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FIELD ARTILLERY SURVEY

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FIELD ARTILLERY SURVEY

Prepared under direction of the Chief of Field Artillery

	Paragraphs
CHAPTER 1. General	1-11
2. Survey echelons	12-18
3. Maps, firing charts, grid systems, and their use:	
SECTION I. General	19-20
II. Fire-control grid	21-27
III. Target-designation grid and polar coordinates	28-29
4. Survey equipment and its use:	
SECTION I. Principal instruments	30
II. Plane table	31-32
III. Tape	33-37
IV. Aiming circle	38-44
V. Transit and accessories	45-54
5. Basic survey operations:	
SECTION I. General	55-59
II. Traverse	60-66
III. Resection	67-70
IV. Long-base intersection	71-73
V. Short-base intersection	74-79
VI. Calculation of distances, *Y*-azimuths, and coordinates	80-81
VII. Astronomical methods	82-84
6. Air photographs:	
SECTION I. General	85-86
II. Tilt, relief, direction, and scale	87-89
III. Mosaics	90-93
IV. Restitution	94-97
7. Survey procedure:	
SECTION I. General	98-99
II. Battle map	100-105
III. Wide-angle photo	106-114
IV. Grid sheet	115-118
V. Mosaics	119-122
VI. Location and laying of base pieces	123-126

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		Paragraphs
CHAPTER 8. Night Survey:		
	SECTION I. General	127-129
	II. Special equipment	130-133
	III. Special methods	134-138
9. Survey plans and examples:		
	SECTION I. Survey plans	139-141
	II. Examples	142-148
		Page
INDEX		137

CHAPTER 1

GENERAL

	Paragraph
Purpose	1
Tables of Organization	2
Latitude	3
Purpose of field artillery survey; engineer cooperation	4
Basis of survey	5
Governed by situation	6
Time required	7
Responsibility for common control	8
Practicability and desirability of common control	9
Modern air photos	10
Training in survey	11

1. Purpose.—This manual is furnished to serve as a guide for the performance of survey operations by division and corps artillery.

2. Tables of Organization.—Since Tables of Organization in general do not specify the personnel to be used for survey, the allotment of duties and responsibilities to the different echelons has been based primarily on the normal functioning of field artillery units in matters of fire direction and preparation of fire. In the division artillery, the survey echelons are the division and the battalion. The regiment, when included in the organization, is not a survey echelon; regarding survey, it exercises only the normal command responsibility for its battalions. In the corps artillery, the major duties have been assigned to the observation battalion and the gun or howitzer battalions.

3. Latitude.—The methods and procedure set forth herein are not inflexible, nor do they cover every situation which may arise. Other methods, or combinations of the prescribed methods, may be used when better suited to the particular situation.

4. Purpose of field artillery survey; engineer cooperation.—*a.* Field artillery survey is concerned primarily with *unobserved*

fires and consists mainly of the topographic operations necessary to permit such fires. The principal object of the survey is to determine with sufficient exactness the relative locations of pieces and targets horizontally and vertically. To facilitate the passing of information obtained by one unit to other units and to assist in the massing of fires, a common grid system or other means of coordination is desirable.

b. It is the responsibility of the chief engineer in the theater of operations to furnish to the artillery, through the engineers of subordinate echelons, appropriate data concerning monuments, bench marks, and other control points in the artillery zone of action in form for use by artillery survey personnel. Insofar as is consistent with their mapping mission, engineer topographic troops will render all assistance possible to artillery survey personnel. Artillery survey detachments, for their part, make maximum use of the survey control data secured incident to the preparation of maps.

5. Basis of survey.—In general, unobserved fires are practicable only when an accurate map or suitable air photos are available. Without such basis, unobserved fires are limited to targets located by sound, flash, or radio position-finder station. In making plans for an operation, due consideration must be given to the availability of suitable maps or air photos. If neither is available, the artillery support, in general, is limited to observed fires.

6. Governed by situation.—The amount and character of survey work required will differ greatly in different situations. An important factor is the map or map substitute available. The survey operations required when an accurate battle map is furnished usually are fewer than when only air photos are employed. Other factors which influence the survey are the fires anticipated, the terrain, the time available, and the possibility of registration. In any case the methods employed should be in keeping with the particular situation. When support is needed and hasty methods will provide satisfactory fires, the opening of fire should not be delayed through the use of slower and more precise methods. When time is available, however, precise methods should always be used. If hasty methods must be used initially to expedite the opening of fire, the survey should be continued in order that inaccuracies may be reduced.

7. Time required.—In the employment of the artillery, corps, division, and other commanders must consider the question of survey. If support by unobserved fires is expected, the artillery must be given time to perform the essential survey. While much of the work may be done at night, certain reconnaissance and certain topographic opera-

tions must be performed during daylight hours. Usually no work on the survey can be accomplished by battalions until the position areas are known. The time required varies so widely in different situations that average figures cannot be stated. The artillery commanders, however, should be able to estimate accurately the time needed in any particular situation.

8. Responsibility for common control.—In unmapped areas, depending upon the time available and the need therefor, a common grid system may or may not be sought. The decision generally rests with army or corps. For the coordination of its battalions, the division may establish local control of some form, such as an arbitrary grid or a line which gives basic location and direction. If a common grid system is to be employed, orders to this effect must be issued, and subordinate units must be furnished the necessary control data. Since the lower echelons do not have the topographical personnel required for the extension of survey over great distances, the higher echelons are responsible that control is pushed forward to points readily accessible to subordinate units.

9. Practicability and desirability of common control.—Except when battle maps are furnished, common control is not always practicable. The time available in moving situations often is insufficient for the execution of the necessary survey. In some situations, only control between particular units, for example, between the observation battalion and the artillery units to be employed on counterbattery, is practicable or desirable. Little advantage is gained by a common grid system unless the target area is accurately controlled; often such control of the target area is impracticable. The wide-angle photo lessens the need for common control because it provides a reasonably adequate coordination without a common grid system.

10. Modern air photos.—Since survey operations are dependent upon the map or map substitute used, it must be expected that these operations will be modified when improvements are made in photographic technique. Greater accuracy and increased coverage are particularly important. The recent development of the wide-angle camera, which produces a reasonably accurate photo covering a large area, has materially simplified the problem of survey. The photo taken by this camera is large enough to include both the artillery positions and the normal targets of division artillery. If taken form an altitude of 30,000 feet, the photo would be large enough to include the corps artillery and the bulk of its targets. The size and accuracy of the photo make its use for horizontal control very much the same as that of a map. The photo automatically ties together

all artillery and all targets located within the area covered, thereby providing coordination formerly possible only through the time-consuming survey necessary when using a smaller photo.

11. Training in survey.—Since artillery must be prepared to operate in unmapped areas, training without maps should be stressed. Survey in moving situations with only air photos should be emphasized. If artillery survey sections are capable of making satisfactory surveys under such conditions, little trouble will be encountered when accurate maps are furnished or when the situation stabilizes. It is possible that, in the time intervening between the production of air photos and the issue of accurate maps, other maps or photomaps, for example, contoured photos, incomplete battle maps, or mosaics, may be furnished. These additional maps or photomaps merely simplify survey procedure; the training with only air photos available prepares the artillery for any situation which may arise.

CHAPTER 2

SURVEY ECHELONS

	Paragraph
General	12
GHQ and army	13
Corps	14
Division	15
Regiment	16
Battalion	17
Battery	18

12. General.—*a.* The survey leading to unobserved fires may be performed by the field artillery unassisted, or by the field artillery assisted by the engineer corps. The field artillery is interested primarily in the determination of the relative locations of pieces and targets; under certain conditions, common control is sought. The engineer corps is concerned primarily with mapping and the survey operations leading to common control.

b. In well-mapped areas, with battle maps available, the field artillery normally performs its own survey without further assistance from the engineers, the basic control data being taken from the details of the map. In unmapped areas, unless common control is to be employed, the field artillery habitually performs all of its own survey work. When common control is to be used, the engineer corps furnishes the basic control for the ground survey.

c. The responsibilities of the various commands and a summary of the survey operations performed by each are listed in this chapter. Each situation, however, will call for an estimate, plans, and choice of methods. Procedure appropriate in one situation may be unsatisfactory in the next. Therefore in any particular situation some of the responsibilities, duties, or operations listed may not be appropriate.

d. Detailed information of engineer survey may be found in TM 5-235. Should the field artillery be required to perform survey operations which are normally the function of the engineer corps, TM 5-235 should be consulted. The survey of the observation battalion in the installation of sound- and flash-ranging establishments is covered in detail in FM 6-120; in this text it will be treated in a general manner only.

13. GHQ and army.—*a.* GHQ or the army is charged with the production of suitable maps of the theater of operations as a whole,

including large-scale maps for field artillery fire control. GHQ or army topographical engineers are used for this purpose.

b. The engineers in their mapping operations establish or extend such primary control as may be necessary and recover existing control points. The degree of accuracy of location of points depends upon the specific purpose of each.

c. Since maps of our own forward areas and positions held by the enemy are of primary importance, the army engineers extend their control as far forward as practicable and are prepared to advance their control as our troops advance. Descriptions and coordinates of control points are published for use by the field artillery and all other arms concerned.

d. On occasion, field artillery, particularly heavy artillery and observation battalions, may find it necessary to obtain data on control points directly from the army topographical engineers.

14. Corps.—*a.* The corps is responsible for any hasty mapping of the area of immediate interest to the corps which must be done prior to the receipt of maps prepared by the army and for the extension of the survey into this area. Starting with the most suitable control points of the army net, the corps establishes a denser net in the area which interests the combat troops. In carrying the control forward, the corps utilizes the corps topographical engineers and the corps observation battalion. The corps also provides map substitutes from air photos; the photographs normally will be made with the wide-angle camera. These photos will be available to the field artillery for use as firing charts.

b. The corps topographical engineers are responsible for coordination with the army engineers, the selection of suitable points to be used as the basis of the corps survey, and the extension of this control to areas readily accessible to the corps observation battalion and other artillery units. When conditions permit, the corps topographical company establishes control points in the artillery position areas and determines the location of points within the enemy's lines.

c. In order that the work of the engineers may be readily used, coordinates and altitudes of all control points are computed and published, together with descriptions and *Y*-azimuths to prominent objects; markers are established at all accessible control points. Where practicable, the descriptions should enable identification on air photos.

d. The topographical information determined by the engineers, if to be used as the basis for artillery fires, must be furnished in time to permit the artillery to do its own survey work. Accordingly,

close liaison between the corps topographical engineers and the appropriate field artillery survey echelons (observation battalion, brigade survey section, or division artillery section) must be maintained. Anticipatory planning, cooperation, and energetic action often are necessary for completion of surveys by the time needed.

e. The observation battalion has a dual function with respect to survey work.

(1) It establishes its own microphone stations and observation posts.

(2) It coordinates and, when necessary, supervises the survey work performed by other field artillery units in the corps sector; maintains liaison with the corps topographical engineers; advises the field artillery with the corps of the plans and progress of the corps survey; reports the availability of control data; and coordinates requests for engineer assistance. Basing its work on the control established by the corps topographical engineers (in special cases by the army engineers), the observation battalion establishes additional control points and determine azimuths for the guidance of the artillery with the corps. When no control data are available, the observation battalion adopts an arbitrary grid system and furnishes the artillery, particularly those units which are to execute counterbattery, with information as to the grid to be used.

15. Division.—The division artillery commander decides upon the survey to be performed, allocates the tasks, including those of the division artillery survey section, and issues the necessary instructions. The division provides for as much coordination of surveys as the time available and other conditions permit. This may be accomplished by the extension of the common grid system or, if such common control is not furnished by the corps, by prescribing direction, vertical control, and scale; this results in coordination comparable to that obtained by a common grid system. The division may also prescribe an arbitrary grid. The survey performed by the division artillery survey section usually has the purpose of coordinating the battalion surveys or the procurement of information which will be of assistance to all battalions.

16. Regiment.—As a command echelon, the regiment is responsible for the survey operations of its battalions. It plans, coordinates, and supervises the battalion surveys to the extent necessary. As a rule, however, the regiment executes no actual survey except in heavy artillery units, in which case it may participate by performing tasks decentralized to it by the artillery brigade. Within the division, survey is accomplished by the division artillery survey sec-

tion and the battalions. In the corps artillery, the observation battalion usually transmits control information directly to the gun or howitzer battalions.

17. Battalion.—The battalion is primarily interested in the construction of a firing chart which will permit the preparation of firing data. Pieces and targets must be located with suitable accuracy; the survey operations are designed to produce this information. The actual operations depend largely on the map, air photo, or other photomap to be used as the basis of the firing chart. With a battle map available, the survey operations consist of determination of location and altitude of batteries, selection of points which establish direction, and provisions to transmit this direction to batteries. When only air photos are available, the information sought is generally the same except that the scale of the photo must be known and vertical control must be provided. As indicated in paragraph 15, the division artillery survey section may furnish certain basic control data.

18. Battery.—The battery normally does little survey except in assisting the battalion in battalion survey operations. It may be required, however, to determine the location and altitude of the base piece with respect to the place mark, or to determine the location of the base piece by inspection or by short traverse from some nearby identifiable terrain feature.

CHAPTER 3

MAPS, FIRING CHARTS, GRID SYSTEMS, AND THEIR USE

		Paragraphs
SECTION I.	General	19-20
II.	Fire-control grid	21-27
III.	Target-designation grid and polar coordinates	28-29

SECTION I

GENERAL

	Paragraph
Definitions	19
Grids	20

19. Definitions.—*a. Map.*—A plane representation of a portion of the earth's surface by means of conventional signs.

b. Photomap.—A general term denoting a reproduction of a vertical air photo, composite, or mosaic.

c. Battle map.—A map prepared normally by photogrammetric means and at a scale of 1:20,000, which is suitable for the tactical and technical needs of all arms.

d. Firing chart.—A firing chart may be a map, photomap, air photo, or grid sheet. On it are plotted, to a known scale, the relative positions of batteries, targets, base and check points, and any other data necessary for the preparation of fire.

20. Grids.—In performing survey operations it is necessary that data be taken from maps or charts and that other data be plotted thereon. Familiarity with the grid systems which may be used, the methods of plotting, and the determination of data are essential.

SECTION II

FIRE-CONTROL GRID

	Paragraph
Description	21
Coordinates	22
Plotting a point from coordinates	23
Measuring the coordinates of a point	24
Use of right-angled scale	25
Measuring and plotting angles with a protractor	26
Measuring and plotting distances	27

21. Description (fig. 1).—*a.* Military maps habitually have a rectangular grid superimposed to facilitate the transmission of informa-

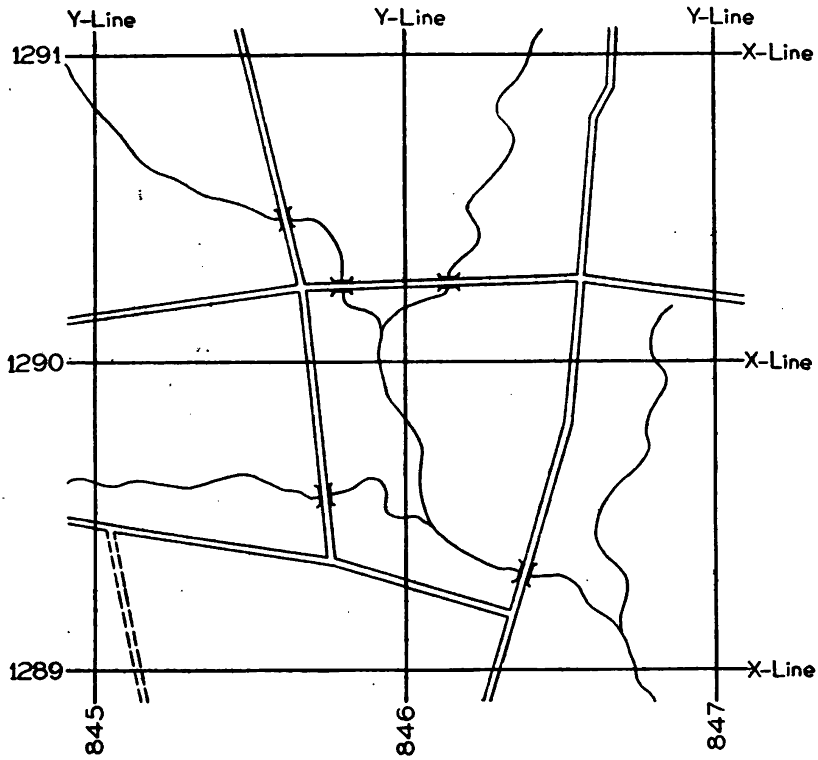


FIGURE 1.—Fire-control grid printed on map.

tion. On battle maps the distance between adjacent grid lines represents 1,000 yards; the scale of the battle map normally is 1:20,000. A grid of this type is known as a *fire-control grid;* the term implies accuracy as to azimuth and scale, and a scale large enough to be suitable for fire control.

b. Grid lines extending north and south are called *Y*-lines; those extending east and west are called *X*-lines. Grids are numbered in accordance with the grid system to which the map conforms. The

battle maps of the United States conform to the standard military grid system of the United States. Other military maps may be provided with a standard grid for the particular theater of operations, or with an arbitrary grid used for a single map or a limited area. When data become available, the standard grid is substituted for the arbitrary grid. There are various methods whereby lines and points compiled on the arbitrary grid may be transferred to the standard grid. The coordinates of at least two points referred to both grid systems must be known; these points enable one grid to be oriented with respect to the other. Points then may be transferred by tracing or by computation. Elevation corrections may be made by addition or subtraction.

22. Coordinates.—*a. Writing coordinates.*—The distance in yards of any point east of the zero *Y*-line is the *X*-coordinate, and the distance north of the zero *X*-line is the *Y*-coordinate. In writing coordinates, the *X*-coordinate is written first and the *Y*-coordinate last, with a dash between, and the whole inclosed in parentheses, thus: (204.729–186.684). A decimal point is used to mark the *thousands* place.

b. Designation of sheet.—The name of the sheet of the map is part of the designation of a point by coordinates; when the map is definitely understood its designation need not be given.

c. Abbreviated coordinates.—(1) If location to the nearest 10 or nearest 100 yards only is desired, or if the measurements cannot be made with greater accuracy, the digits indicating units or tens, respectively, may be omitted. Thus the coordinates of a point may be written—

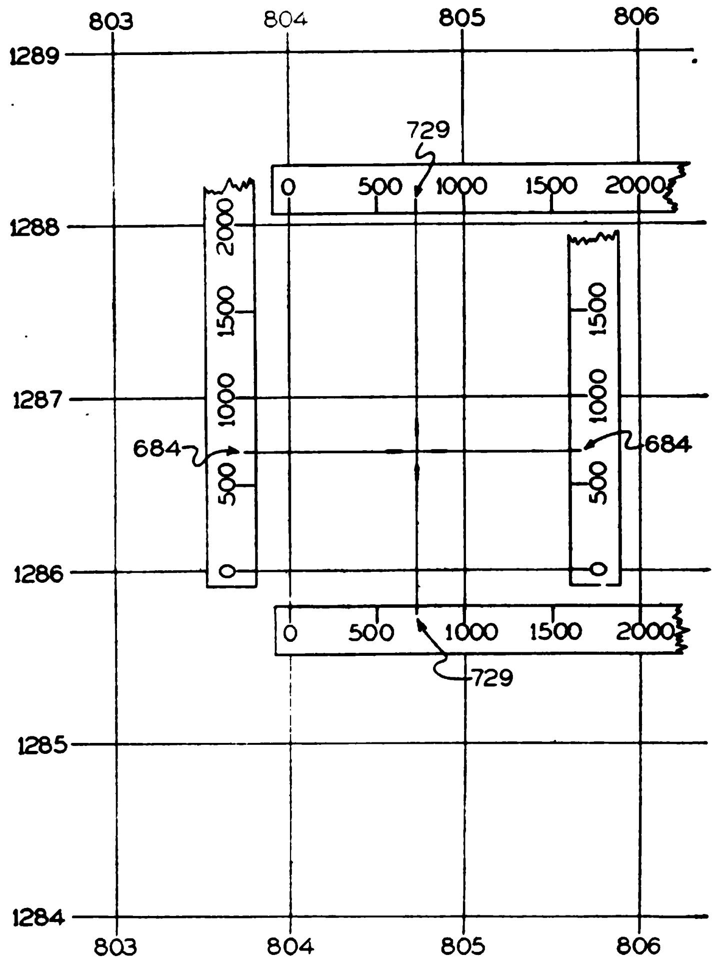
(204.729–186.684)	To the nearest yard.
(204.73–186.68)	To the nearest 10 yards.
(204.7–186.7)	To the nearest 100 yards.

(2) It seldom is necessary to give more than two digits left of the decimal for each coordinate. The coordinates for the point given above then would be (04.729–86.684).

(3) If the point is fixed within an area 10,000 yards square, only one digit need be given before the decimal point of each coordinate. The coordinates of the point would be (4.729–6.684); to the nearest 100 yards (4.7–6.7). If a large number of points are being designated by the latter abbreviated coordinates, the decimals and dash may be omitted, thus: (4767).

23. Plotting a point from coordinates.—*a. Normal grid* (fig. 2 ①).—To plot a point whose coordinates are (804.729–1286.684),

place the zero of the scale on *Y*-line 804.000, and the 1,000-yard point on *Y*-line 805.000. Holding the scale about one square above the approximate location of the point, mark 729 yards with a finely pointed pencil. Place the scale about one square below the approximate location of the point, repeat the operation, and connect the two marks with a fine, light line. This will be the *Y*-line passing through the



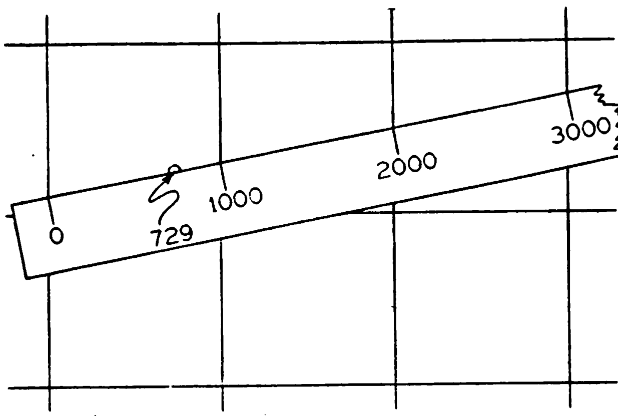
① Normal grid.

FIGURE 2.—Plotting coordinates.

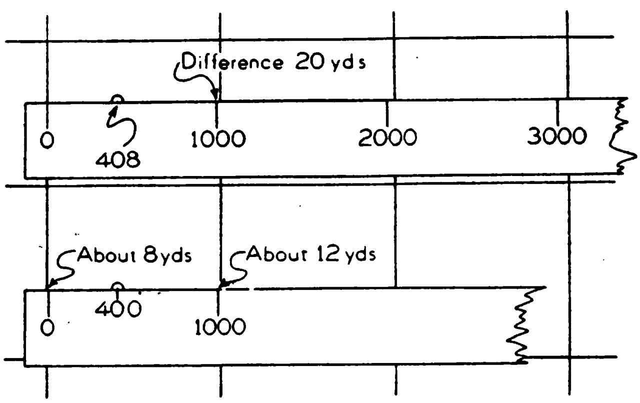
point. In a similar manner determine the *X*-line passing through the point. The intersection of these lines is the location of the desired point. If the plotted point is to be used a number of times, the intersection of the lines is pricked with a fine needle to prevent erasure, and the lines in the vicinity of the point should be accentuated with a soft pencil. These lines, however, do not extend to the point.

b. Grid lines closer than normal (fig. 2 ②).—Plot the point as before, inclining the scale so that the zero is on one grid line and the 1000-yard point is on the other. The point then will be plotted in its true relation to the grid, as the digits after the decimal point express the proportional part of the distance between grid lines.

c. Grid lines more distant than normal (fig. 2③).—Measure the distance between the grid lines and find the difference from normal.



③ Grid lines closer than normal.



③ Grid lines more distant than normal.

FIGURE 2.—Plotting coordinates—Continued.

The proportional part of this difference is added to a measurement. For example, if the distance between grids measures 1020, the difference from normal is 20 yards, and the proportional part of this difference for a 400-yard measurement is $^{400}/_{1000}$ of 20, or 8 yards. The measurement is scaled as 408 yards. If a point is plotted about midway between the grid lines, the measurement may be approximated with satisfactory accuracy by placing intermediate divisions of the scale, such as 1000–2000, at equal distances from the proper grid lines and making a direct measurement of the distance desired.

24. Measuring the coordinates of a point.—Coordinates are measured in the same manner in which they are plotted except that the distance is read directly between the point and the grid line (fig. 2①). Write the number shown at the top or bottom of the *Y*-line west of the point; place a decimal point and write the distance of the point from this *Y*-line. Place a dash, then the number shown at the right or left end of the *X*-line below the point; place a decimal point, then write the distance of the point from this line. Inclose the whole in parentheses. If abbreviated coordinates are desired, make the measurements to the nearest 10 or 100 yards, depending upon the approximation desired. If the grid lines are not standard distances apart, the measurements are made as described for plotting points.

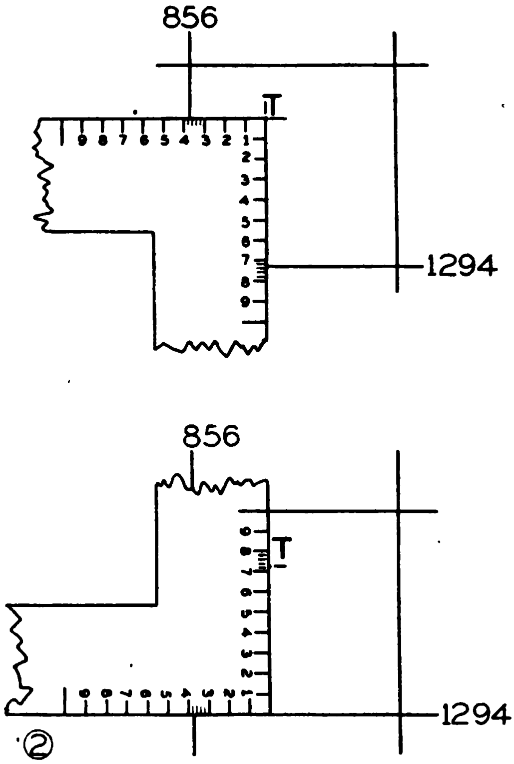
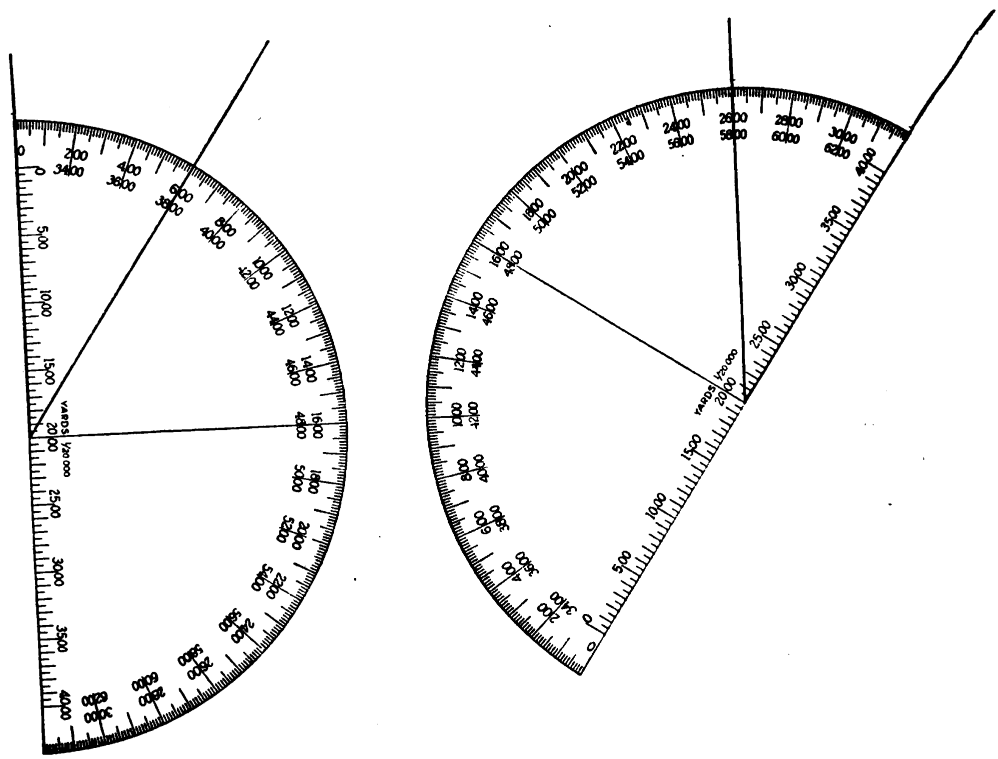


FIGURE 3.—Measuring and plotting coordinates.

25. Use of right-angled scale.—The method of plotting described in paragraph 23 is accurate but rather slow for fire-control purposes. With any right-angled device, such as the one shown in figure 3, points may be plotted and measured more quickly and possibly just as accurately. The scale may be placed in either of the two positions shown, its edges being parallel to the grid lines in each

case. In figure 3①, a tilt of 45 mils causes an error of only 1 yard per thousand in each direction (X and Y).

26. Measuring and plotting angles with a protractor (fig. 4).—*a. General.*—It is essential that the center of the protractor be placed exactly over the vertex of the angle and the straightedge exactly over one side of the angle. For greater accuracy, measure the angle from both sides of the protractor and take the mean of the readings. For example, measure first with the arc to the right of the center; then with the arc to the left of the center. With the protractor shown, the second reading is subtracted from 3200 or 6400 to check with the first, or the graduations are counted; the difference, if any, between the angles will be small. The mean of the readings is taken.

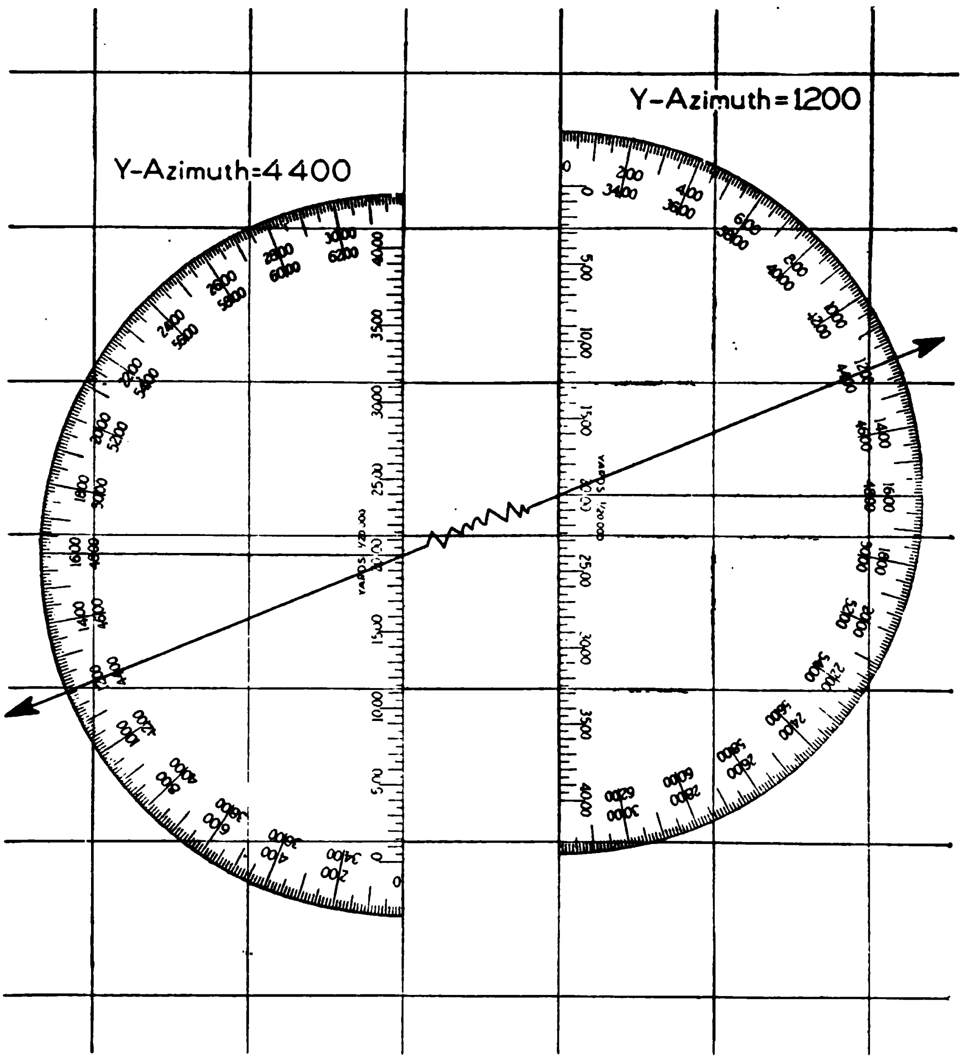


① Direct reading. ② Check reading.

FIGURE 4.—Measuring an angle of 600 mils with a protractor.

b. Y-azimuth.—(1) *Measurement from a Y-line* (fig. 5①).—The Y-azimuth of a line can be measured by using the intersection of this line with a Y-line. The protractor is placed so that the clockwise angle Y-line to given line, is read. If the Y-azimuth is greater than 3200, the proper relation of the measured angle to 3200 or 6400 must be determined.

(2) *Measurement from an X-line* (fig. 5②).—The *Y*-azimuth may also be measured by using the intersection of the line with an *X*-line. Place the 1600-point of the protractor on the *X*-line, and the reading of the line is the *Y*-azimuth. If the *Y*-azimuth is greater than 3200 mils, the proper relation of the measured angle to 3200 or 6400 must be determined.

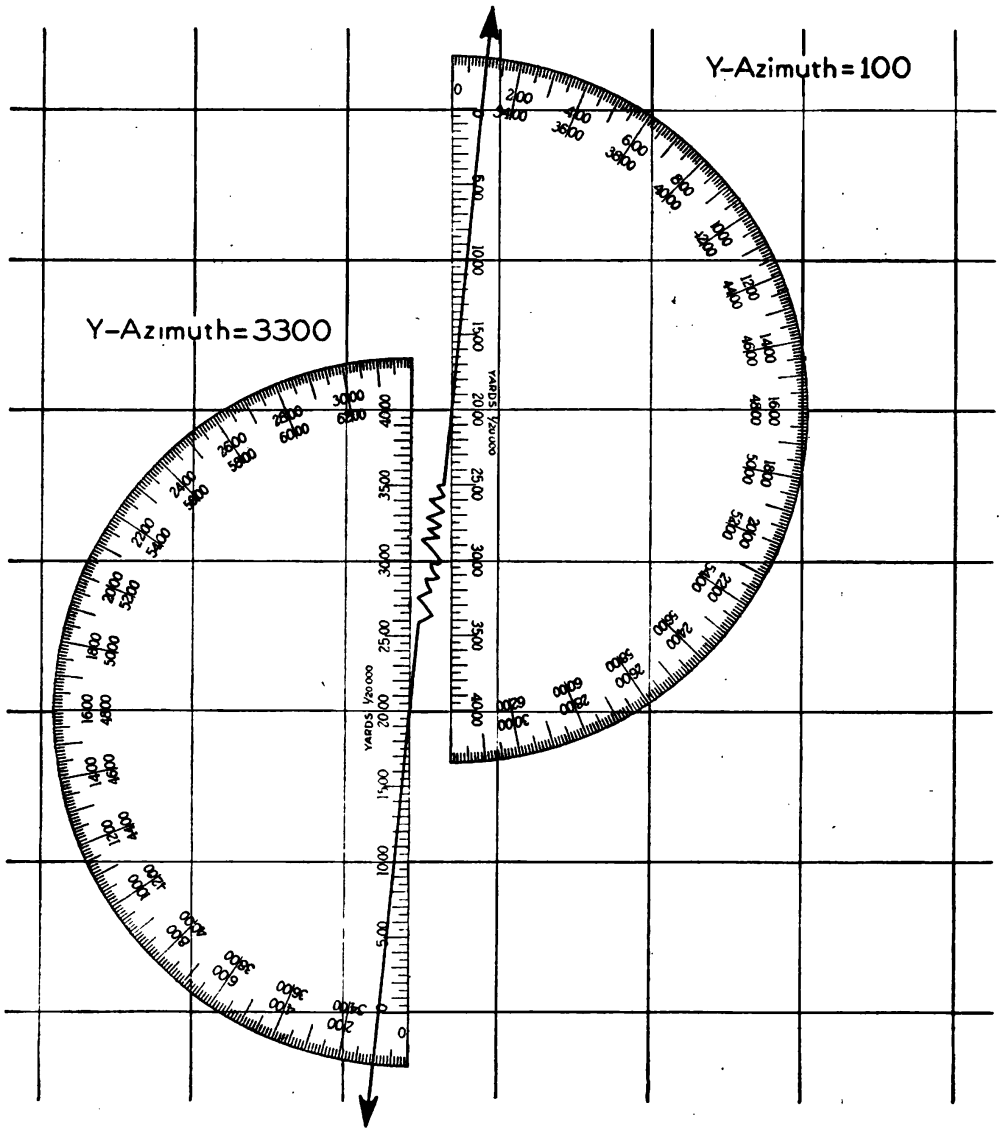


① Using a Y-line.

FIGURE 5.—Measuring Y-azimuth with a protractor.

(3) *To draw a line of given Y-azimuth through a point* (fig. 6).—If the point is on either an *X*-line or a *Y*-line, the line is drawn in the same manner as for measurement of *Y*-azimuth described above. If the point is not on a grid line, the protractor is placed so that its center is on a *Y*-line near the point, at an angle with the *Y*-line equal

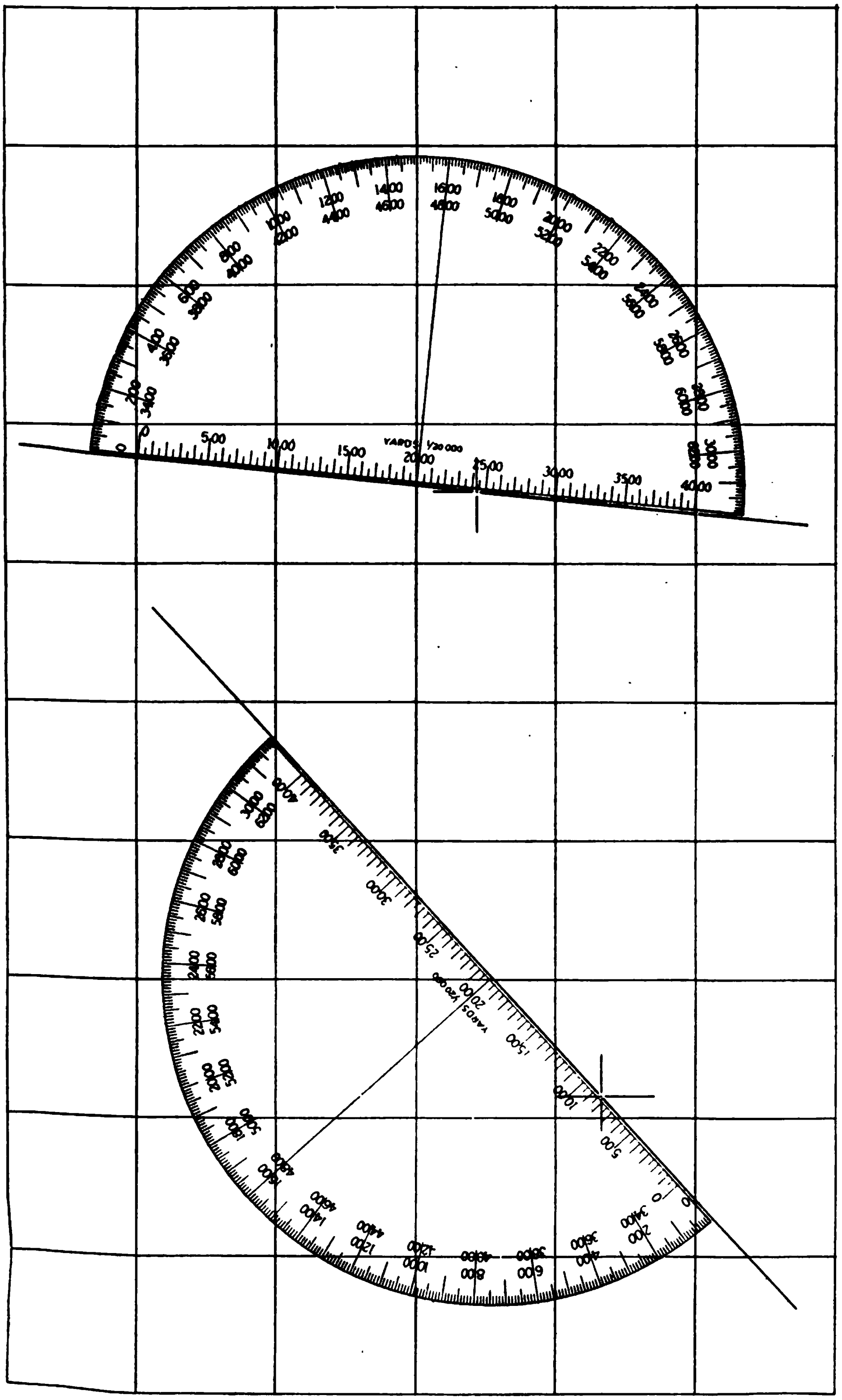
to the given Y-azimuth (less 3200 if necessary), and so that the 0–3200 line of the protractor passes through the point. The line is drawn along the straightedge. If the Y-azimuth is near zero or 3200, it may be more convenient to draw the line with respect to an X-line; the same principle is followed.



② Using an X-line.

FIGURE 5.—Measuring Y-azimuth with a protractor—Continued.

27. Measuring and plotting distances.—*a. Measuring.*—Distances are measured by accurate scales graduated in yards. If the grid lines of a fire-control map are not a standard distance apart, allowance is made for the difference of the scale of the map from



① Y-azimuth 4050 or 850. ② Y-azimuth 100 or 3300.

FIGURE 6.—Drawing a line of given Y-azimuth through a point.

normal. For example, if the distance between adjacent grid lines measures 990 yards, distances measured with the scale should be increased 10 yards for each thousand (1 percent). Maps usually stretch more in one direction than in the other, and this is considered when correcting ranges.

b. Plotting.—The most accurate method of plotting a distance is to plot the extremities, using coordinates. Otherwise, plotting is done in a manner analogous to that of measuring (*a* above); the direction must be accurately laid out and the necessary points marked with a fine needle.

Section III

TARGET-DESIGNATION GRID AND POLAR COORDINATES

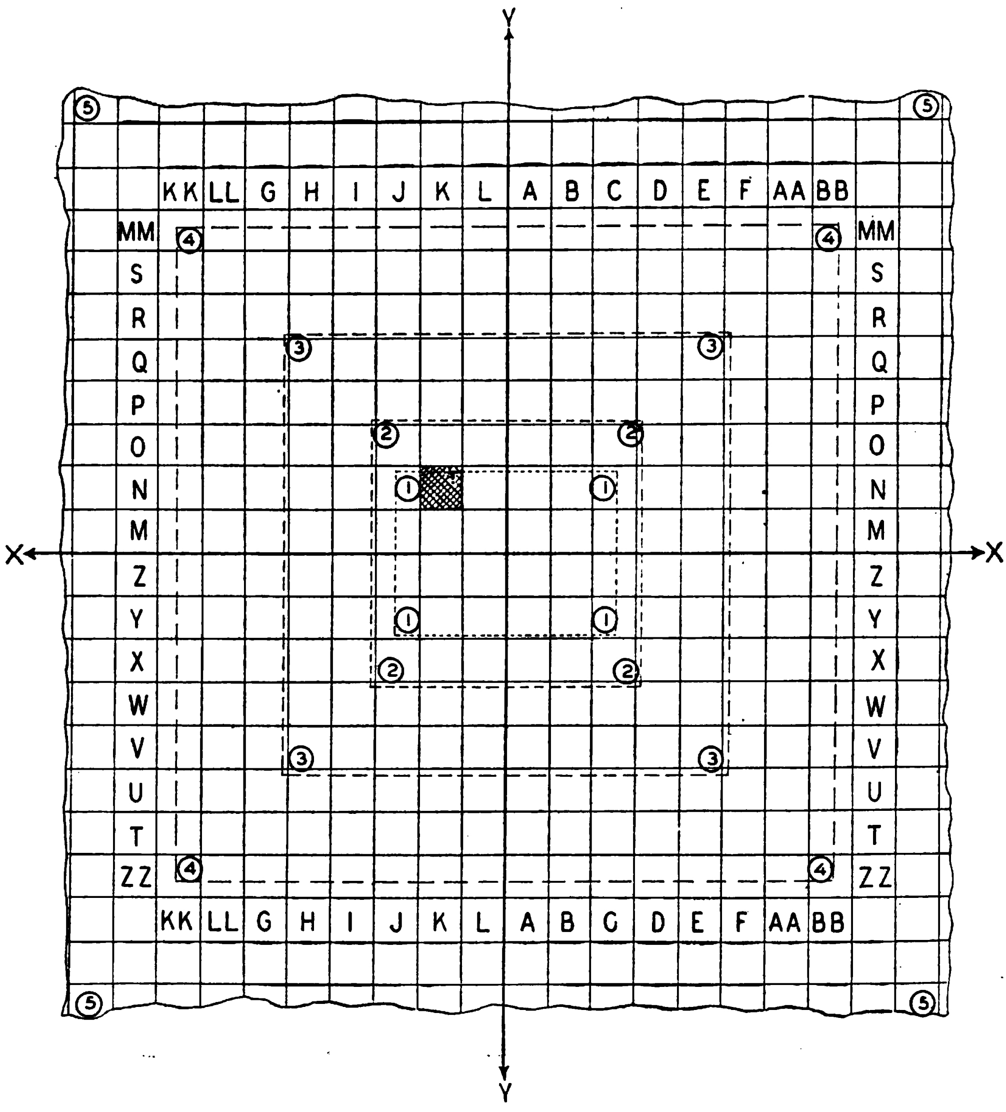
Paragraph
Target-designation grid ---------- 28
Polar coordinates ---------- 29

28. Target-designation grid.—*a.* The printing of an accurate fire-control grid on air photos usually is impracticable because of distortion. Therefore a special or target-designation grid is necessary. This grid has no relation to the actual scale or orientation of the photo; it serves only for point or target-designation and normally is not suitable for measurements of distances and azimuths. For convenience, the dimension of the grid square is 1.8 inches; the 1:20,000 scale may then be used for determining coordinates.

b. The target-designation grid may be printed on the photo, or, for photos without the grid, a transparent template with the grid printed thereon may be used. It is essential that all concerned place the template on the photo in exactly the same manner; standard markings on the photo permit identical placing.

c. One type of target-designation grid is illustrated in figure 7.

29. Polar coordinates.—On ungridded maps or photos, points may be designated by an angular measurement from a determined direction and a distance from a known point. The angular measurement and distance are known as *polar coordinates.* The angle is measured in a clockwise direction. The distance may be measured with a 1:20,000 scale or the scale of map or photo may be used. A point with polar coordinates (Az 1350, 3800) is plotted with a clockwise angle of 1350 mils and a distance of 3800 yards. The point of origin, the direction from which to measure the angle, and the scale to be used must be prearranged. Polar coordinates usually require more prearrangement and are slower and less accurate than the target-designation grid.



1. Single vertical photo, K-3B camera.
2. Vertical portion of composite photo, T-3A camera.
3. Wide-angle photo taken at 20,000 feet.
4. Wide-angle photo taken at 30,000 feet.
5. Map or mosaic with fire-control grid or other wide-coverage grid.

FIGURE 7.—Transparent template with target-designation grid.

Chapter 4

SURVEY EQUIPMENT AND ITS USE

		Paragraphs
Section I.	Principal instruments	30
II.	Plane table	31-32
III.	Tape	33-37
IV.	Aiming circle	38-44
V.	Transit and accessories	45-54

Section I

PRINCIPAL INSTRUMENTS

	Paragraph
Principal instruments	30

30. Principal instruments.—The principal instruments used for survey operations are the plane table and its accessories, the tape, the aiming circle, and the transit and its accessories. Detailed descriptions of the plane table, tape, and the transit are given in TM 5-235.

Section II

PLANE TABLE

	Paragraph
Plane table and accessories	31
Use	32

31. Plane table and accessories.—The plane table consists of a drawing board and a tripod. The tripod is so arranged with a ball and socket joint that the board can be leveled independently of the position of the legs and can be rotated in a horizontal plane when level. The major accessories generally are—

a. A *declinator* (or needle) which may be used to orient the board roughly.

b. A *protractor* which is used to plot and measure angles as shown in chapter 3.

c. A *scale* which has graduations in yards, usually to a scale of 1:20,000. The triangular scale, also used as an alidade, is graduated to several scales besides 1:20,000.

d. An *alidade* which is used to perform graphic survey on the plane table. Alidades are of three kinds: the triangular scale, the open-sight alidade, and the telescopic alidade.

32. Use.—*a. General.*—Survey work may be done on the plane table directly, or readings may be taken with an instrument and the results plotted on the board. Plane-table survey, while reasonably accurate, has the disadvantages that the table is conspicuous, bulky to carry, and difficult to use in inclement weather.

b. To attach the grid or map.—The sheet is fastened to the table so that the grid lines are parallel to the edges of the table. The sheet may be larger than the table, with the surplus folded over the edges and fastened with brass thumbtacks. A strip of cardboard or heavy paper placed along the edge of the sheet under the tacks will prevent tearing. A sheet slightly smaller than the table, fastened with cellulose (Scotch) tape, is also convenient and satisfactory. A waterproof cover is desirable to protect the work on the table.

c. To set up the plane table.—Set up the table approximately level, two legs being placed downhill if the board is on a slope. In general, it is sufficiently accurate to set the center of the table, by eye, over the station point.

d. To level the plane table.—The plane table must be level. When the points sighted upon are distant, it usually is sufficiently accurate to level the plane table by eye. For greater precision, the table should be leveled accurately, using a bubble.

Section III

TAPE

	Paragraph
Tape and accessories	33
Measurements and precision	34
Taping methods	35
Tapemen's duties	36
Training	37

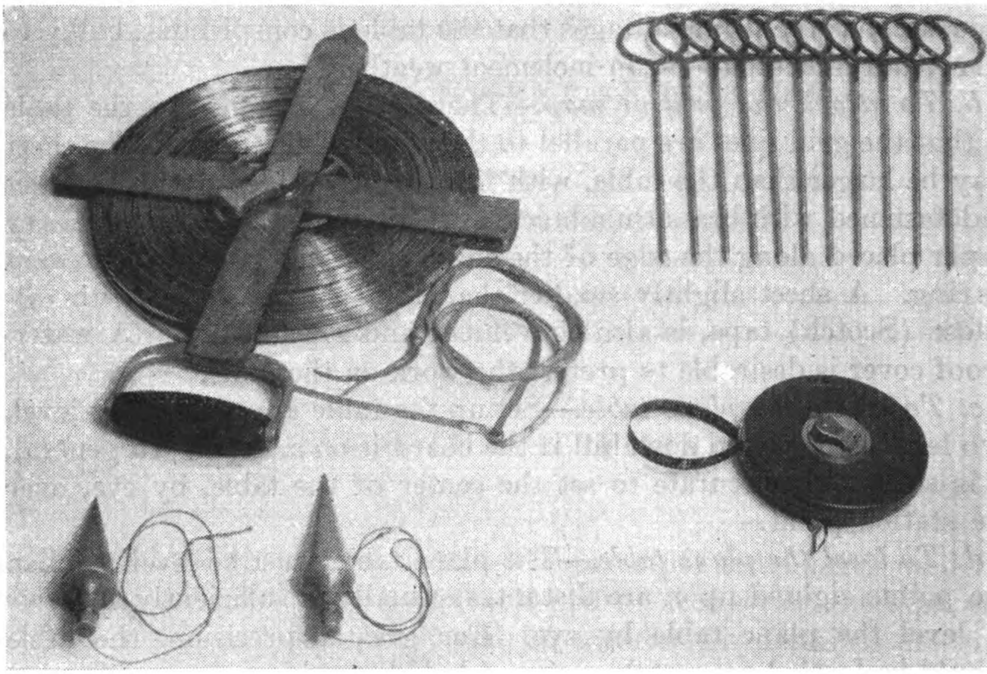
33. Tape and accessories.—*a. Tape.*—(1) Field artillery survey sections are equipped with 300- and 100-foot tapes. The 300-foot tapes are ordinarily used; 100-foot tapes being preferable when working in woods, on steep slopes, or in heavy traffic.

(2) The 300-foot tape is graduated at intervals of 1 foot, with the first and last foot graduated into tenths of a foot.

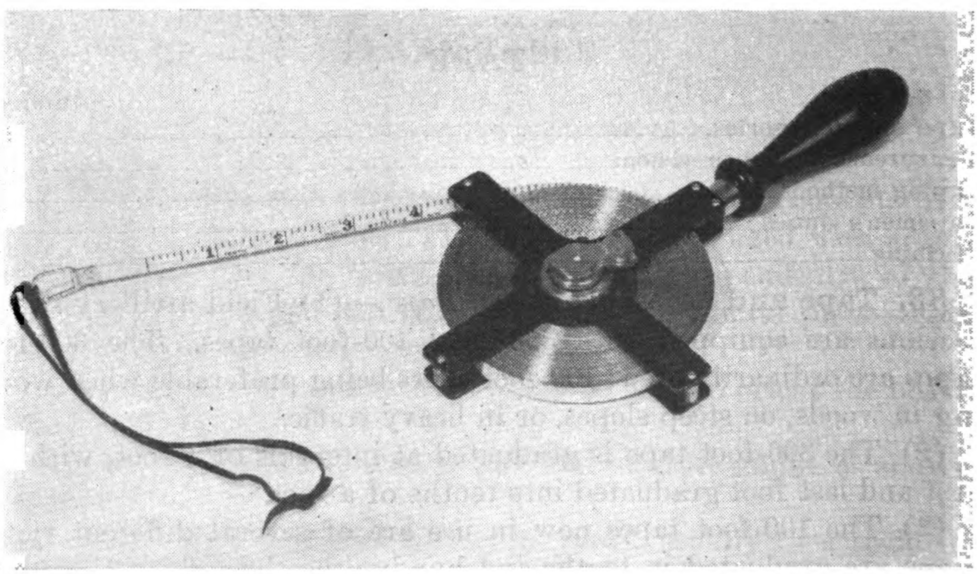
(3) The 100-foot tapes now in use are of several different types. Some are graduated in tenths and hundredths throughout the entire length; others have graduations similar to the 300-foot tape.

b. Accessories.—Each tapeman should be equipped with a plumb bob and cord, a plumb-bob belt sheath, a hand level, and a notebook. The head tapeman should have a set of 11 chaining pins.

34. Measurements and precision.—*a. Horizontal and slope measurements.*—The method customarily used in field artillery survey



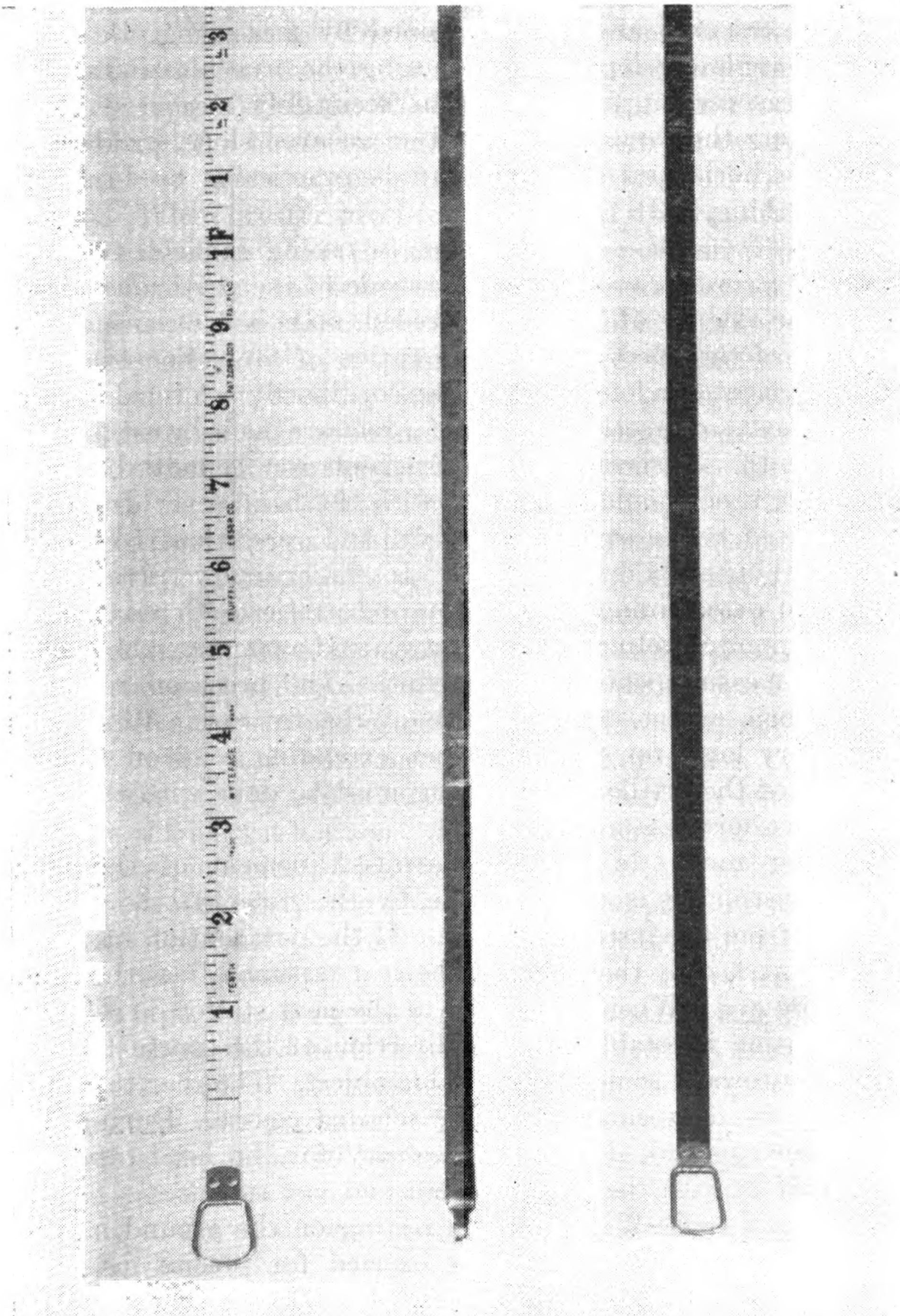
① Tapes and accessories.



② 100-foot tape.

FIGURE 8.—Various tapes and accessories.

is to hold the tape horizontal, using plumb bobs on slopes to project tape lengths or fractions of tape lengths to the ground. The meas-



③ Graduated tape ends.

FIGURE 8.—Various tapes and accessories—Continued.

urement of a fraction of a tape length on a slope is called "breaking tape." Distances may also be determined by measuring the slope distance and angle of slope and computing the true horizontal distance. A measurement made with an accurately measured slope angle, providing the tape is supported at an even slope, produces a more accurate horizontal distance than is practicable by breaking tape and plumbing.

b. Precision required.—The precision in taping in field artillery survey varies according to the use to be made of the particular measurement. The degree of precision needed may be determined by consideration of the effect on the preparation of fire. For example, in the measurement of a long base, the tape ordinarily is leveled by eye, and measurements of fractional parts of a foot are made by estimating the nearest tenth. A short-base measurement usually must be more accurate. The tape should be leveled with the hand level, fractions of a foot should be measured accurately, and repetitions to assure accurate plumbing should be the rule. In the ordinary traverse for the purpose of determining the location of batteries with relation to some selected point, leveling the tape by eye and estimating the tenths in fractional measurements is satisfactory. The precision required depends to some extent on the length of the traverse. When the traverse is very long, for example, when extending common control into the area of the artillery, the taping must be done with the precision used for short-base measurements.

35. Taping methods.—*a. Alinement.*—Alinement of the tape during the measuring is usually done by the tapemen themselves without help from the instrument man. If the next station has been selected it is marked by the rodman; the rear tapeman lines the head tapeman in by eye. When the course to the next station is selected before the station is established, the direction of the course habitually should be toward some unmistakable object. The rear tapeman then lines the head tapeman in on the selected course. During the crossing of low ground, it may be necessary for the head tapeman to line himself in with the rear tapeman and last station.

b. Tension and sag.—With the tape resting on the ground, a pull of approximately 20 pounds must be exerted for precise measurements. When the tape is suspended in the air for plumbing, the tension should be increased to remove the sag; an unsupported length of about 100 feet requires a pull of about 25 pounds. Unsupported lengths greater than 100 feet introduce errors in measurements and should not be used in a precise survey.

c. Fractional readings.—Taping usually is done with the zero end of the tape forward. The manner of making fractional measurements depends on the graduations of the tape and method used in breaking tape. With the 300-foot tape, except when a precise survey is necessary, the head tapeman holds the zero on the forward point and the rear tapeman reads the footmark and estimates the tenths of feet. When greater precision is required, the rear tapeman, while the head tapeman holds the zero mark short of and within a foot of the forward point, reads and calls out the measurement in feet. The rear tapeman then slacks the tape *1 foot*, holding the new footmark accurately over the rear point. The head tapeman measures the fraction of a foot, reading *backwards* on the graduations on the first foot of the tape. He announces the total distance, and both tapemen enter it in their notebooks.

d. Breaking tape.—Measurement by breaking tape is done as follows: The head tapeman pulls out a length of tape that can be stretched horizontally. Except for a very short section, the elevated end should not be held above shoulder high. The head tapeman should make the break so that the rear tapeman can hold at a 10-foot mark. For a precise survey, leveling of the tape is done with a hand level; by the head tapeman when the course is going downhill, and by the rear tapeman when it is running up grade. For a less precise survey, leveling the tape by eye is satisfactory, particularly when assisted by the view of a distant horizon. The mark on the end of the tape section which is not in contact with the ground must be held by means of the plumb bob accurately over the point marked or to be marked on the ground. The head tapeman marks each break with a chaining pin. An alternate method of breaking tape, particularly suitable for the 100-foot tape, is to drag the tape forward its full length. The head tapeman then comes back to a 10-foot mark which permits a section at the rear end of the tape to be held horizontal. He marks the measurement on the ground. The rear tapeman then comes forward and holds the same 10-foot mark over the indicated point. This method permits the recording of only complete tape lengths during the breaking of the tape; intermediate points are not marked with chaining pins.

36. Tapemen's duties.—*a. Head tapeman.*—The head tapeman points out to the rear tapeman the line of the next course; pulls out the tape to the limit allowed by the slope of the ground; determines the necessary height to level the tape when running down grade; exerts the proper tension on the tape; and calls "Ready." When he hears "All right here" from the rear tapeman, he marks the spot with a

chaining pin, or, if running downhill, he releases his plumb-bob string and marks with a chaining pin the spot where the point of the plumb bob falls. As soon as he completes the measurement he calls "All right." He leaves a chaining pin at each point. On reaching the end of the course he measures to the station mark or if the station has not been established he sets the station mark.

b. Rear tapeman.—The rear tapeman alines the head tapeman. When the head tapeman calls "Ready," he holds the proper tape graduation exactly over the mark on the ground and calls "All right here." He continues to hold his end of the tape accurately in place until the head tapeman calls "All right." He recovers the chaining pins which the head tapeman has used in marking the points on the ground. At the end of each course, he counts the pins he has collected and sees that the number corresponds to the number of measurements recorded. When the course is running uphill, he determines the lengths of the breaks which can be made and is responsible that the tape is held level.

c. Tapemen's notes.—Both tapemen keep independent records of all measured distances. At the end of each course, each tapeman adds the measurements and records the total distance in his notebook before comparing his results with those of the other tapeman. When they do not agree the course must be retaped. No erasures should be made. A single line should be drawn through an erroneous figure, and the correct figure should be written above or below it.

37. Training.—*a.* Tapemen should be carefully trained in the proper procedure. Prescribed methods should be rigidly enforced. Constant vigilance must be exercised by tapemen to avoid errors and blunders. The most common blunders are the misreading of the figures on the tape and the loss of a complete tape length or a plumbed section.

b. Don'ts for tapeman.

(1) Don't jerk the tape.

(2) Don't pull the tape when kinked.

(3) Don't let vehicles run over the tape; don't let a horse step on it.

(4) Don't bend the tape sharply around corners.

(5) Don't split hairs in lining in.

(6) Don't allow the chaining pin to be disturbed.

(7) Don't pull the pin until you are sure that it will not be needed again.

(8) Don't "break tape" oftener than necessary. Each break slows up the work and introduces another chance for error.

(9) Don't fail to wipe the tape clean and dry before putting it away.

(10) Don't forget that methodical procedure prevents errors and makes speed.

SECTION IV

AIMING CIRCLE

	Paragraph
Use	38
Measuring horizontal angles	39
Measuring vertical angles	40
Centering the needle	41
Declinating the aiming circle	42
Laying the instrument on a given *Y*-azimuth	43
Measuring *Y*-azimuth	44

38. Use.—In survey, the aiming circle is used to measure horizontal angles, limited vertical angles, and *Y*-azimuths.

39. Measuring horizontal angles.—To obtain accurate measurements, the spherical bubble should be centered and the following precautions should be taken:

a. The last movement of the vertical hair when being set on an object is always made in the same direction, usually clockwise. If the object is overrun, the hair is moved well back of the object and run up to it again. This eliminates the effect of lost motion.

b. As a check, after making a measurement, the hair is brought back to the origin. If the index varies materially from the proper reading, the measurement is thrown out.

c. When extreme accuracy is desired, measurements are repeated cumulatively 3 to 6 times, and the average taken. For example: The angle between two points *A* and *B* is to be measured cumulatively 3 times. With the scale set at zero, the line of sighting of the instrument is directed at *A* with the lower motion. The angle to *B* is measured with the upper motion (assume reading 205 mils). The instrument is again directed at *A* with the lower motion without changing the reading and the angle measured again (assume reading 408 mils). The angle is measured a third time in the same manner (assume reading 613 mils). This value, 613 mils, is divided by the number of readings to give 613/3 or 204.3 mils. This is the value of the angle desired.

40. Measuring vertical angles.—For reliable work, the instrument should be accurately tested and its correction constant determined.

41. Centering the needle.—For precise work, the average of several trials is taken as follows:

a. Set the scales at zero and center the needle with the lower motion.

b. Using the upper motion, bring the line of sighting to some well-defined object and note the scale reading.

c. Repeat the operations 3 to 6 times and take the average of the readings.

d. Set this average on the scales and lay on the object. The 0-3200 line of the instrument will be on compass north.

42. Declinating the aiming circle.—*a.* Set up the aiming circle over a point from which several points of known *Y*-azimuth can be seen. These points should lie in different quarters of the compass. Level the instrument carefully. Set the scale at zero and center the needle. With the upper motion turn successively to the known points and record the readings. Check by continuing around to the first point read, and if the readings on this point differ by more than 1 mil, the measurements are thrown out and the readings are made again. Subtract the compass reading to each of the points from its known *Y*-azimuth. The average of the differences is the declination constant of the instrument.

b. Example.—From the declinating station four points of known *Y*-azimuth can be seen. The scales of the aiming circle are set at zero and the needle centered as described in paragraph 41. Three readings are made to each point; the mean readings and the computation of the declination constant are as follows:

Point	Actual *Y*-azimuth	Compass reading (mean of three readings)	Difference
1	5183	5015	168
2	88 (6488)	6322	166
3	1739	1572	167
4	3675	3508	167
Total			668
Average			167

The declination constant of the instrument is recorded as *167*.

43. Laying the instrument on a given *Y*-azimuth.—To place the 0-3200 line of the instrument on *Y*-north, center the needle with the declination constant set on the scales. To place the 0-3200 line of the instrument on a line of designated *Y*-azimuth, subtract this azimuth from the declination constant (with 6400 added when neces-

sary), set the remainder on the scale, and center the needle by moving the *lower* motion.

44. Measuring *Y*-azimuth.—To measure the *Y*-azimuth to a point, the declination constant is set on the scales and the needle centered, using the lower motion. The vertical hair is brought to the point by use of the upper motion and the *Y*-azimuth read on the scales.

Section V

TRANSIT AND ACCESSORIES

	Paragraph
Use	45
Verniers	46
Setting up transit	47
Classification of horizontal angles	48
To measure a horizontal angle	49
Angles by repetition	50
To measure a vertical angle	51
To run or prolong a straight line	52
Range poles	53
Stadia	54

45. Use.—*a.* The transit (fig. 9) is used for measuring horizontal and vertical angles, for prolonging straight lines with accuracy, for leveling, for compass surveys, and for measuring distances by stadia. The transit is used by field artillery survey sections for all work requiring accuracy in the measurement of angles.

b. The transits now used by the field artillery are graduated in degrees and minutes. New transits may be graduated to 20 seconds.

46. Verniers.—*a.* All transits are equipped with verniers. A vernier is an auxiliary scale used for reading fractions of the smallest division of the main scale. The use of a vernier is based on the fact that it is easier to determine coincidence of two lines than to estimate fractions of a scale interval. Figure 10① shows a rod vernier; in each diagram the vernier appears on the left and the main scale on the right. A distance equal to nine divisions of the main scale is divided into ten equal parts, and it is placed edge to edge with the main scale (left-hand diagram). As the vernier moves upward, no lines are coincident until it has moved one-tenth of a main subdivision; at this time the first division line of the vernier coincides with a line of the main scale. When the vernier has moved two-tenths of a main subdivision, its second division line coincides with the next line of the main scale, and so on. When the vernier reaches the point intended as a measurement, the position of its zero arrow indicates the reading desired. For example, in figure

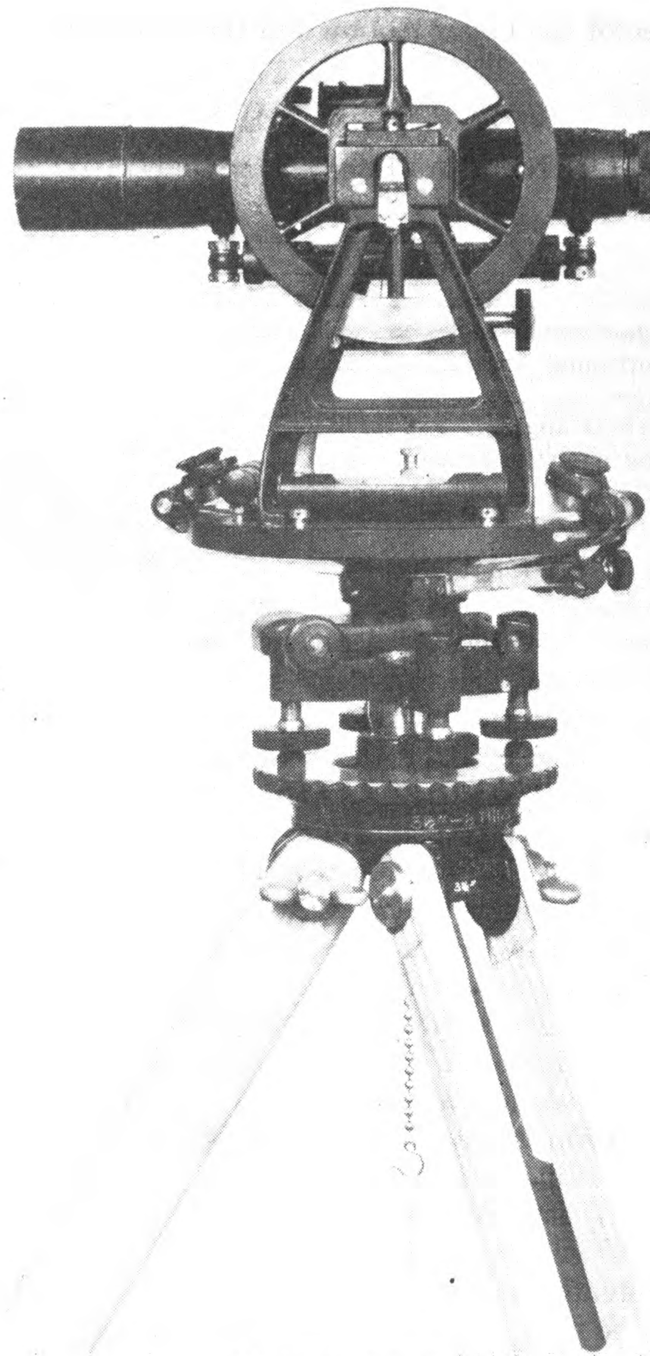


FIGURE 9.—Transit.

10①, right-hand diagram, the arrow lies between 5.1 and 5.2, and the seventh subdivision of the vernier is coincident with a subdivision of the main scale; the reading is therefore 5.17.

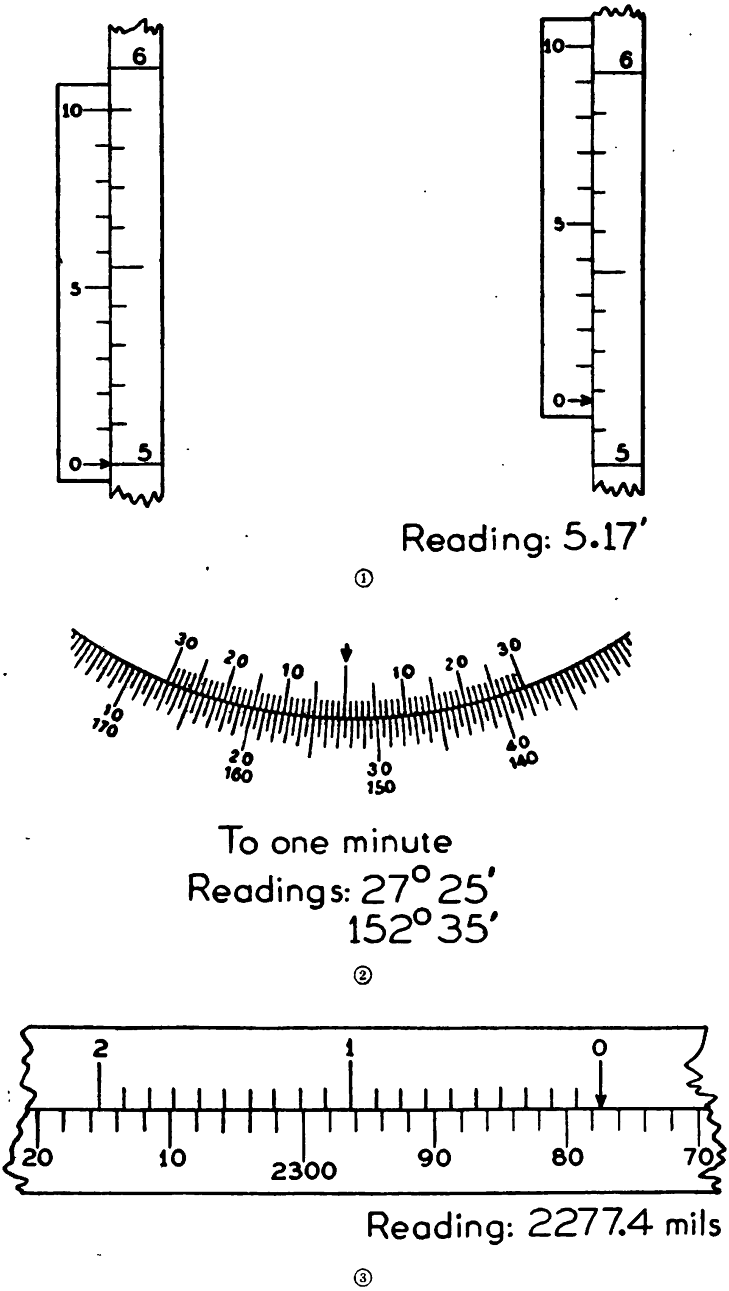


Figure 10.—Vernier readings.

b. It will be noted in figure 10① that the subdivision of the vernier is *one-tenth* less than that of the main scale, thereby permitting readings to *one-tenth* of the smallest main-scale division. This same

principle applies regardless of the fraction desired. For example, if a reading of one thirtieth of the main-scale division is required, then the corresponding division on the vernier will be twenty-nine thirtieths of this main-scale division. This is the case for many transits which are graduated to ½°, or 30′. The vernier then reads to 1 minute (one thirtieth of the smallest main-scale division). This is shown in figure 10②. Unlike the rod vernier, graduations extend on both sides of the index arrow.

c. In figure 10③ there is shown a main scale with a smallest subdivision of two mils. If it is desired to read to one tenth of a mil, the vernier must give readings of one twentieth of two mils, and therefore its twenty subdivisions lie opposite nineteen subdivisions on the main scale.

47. Setting up transit.—*a.* When setting up the transit, place one of the tripod legs in approximately the correct position with reference to the station mark; then manipulate the other two legs so that the plumb bob is brought over the mark, at the same time keeping the leveling head approximately level. On hillsides, one tripod leg should be uphill, the other two downhill. Keep the tripod bolt nuts sufficiently tight so that they will just sustain the weight of the legs when the instrument is lifted. Press the tripod shoes firmly into the ground to aid rigidity. If the plumb bob is nearly over the mark, final centering may be made by moving the shifting plate after loosening the leveling screws.

b. When leveling the instrument, turn the plates so that each plate level is parallel to a pair of diagonally opposite leveling screws. Great care should be exercised when leveling; the screws must not be loose as this results in the plates tipping and, possibly, a horizontal movement changing the position of the plumb bob over the mark. The screws must not be too tight as this injures the instrument and strains the metal, thereby causing errors. To level, grasp one pair of opposite screws between the thumbs and forefingers and turn so that the thumbs move toward each other or away from each other, thus tightening one screw and loosening the other. The motion of the two screws should be uniform to prevent binding; if binding occurs, it is remedied by turning the screw being loosened faster than the other one. If this does not relieve the binding, the opposite pair of screws is causing the trouble and should be loosened slightly. After one bubble has been brought nearly to the center of its tube the other bubble is centered in a similar way. Instead of getting one bubble centered exactly, it is better to get both bubbles approximately level, after which one bubble and then the other may

be exactly centered. After the instrument is leveled, check the plumb bob to see that it has not been moved from the mark during the leveling process.

48. Classification of horizontal angles.—*a.* Horizontal angles are sometimes classified as—

(1) *Interior angles, or the inside angles at the vertices of a polygon* (fig. 11①).—This system of angles is often used for area surveys and when running counterclockwise around a circuit.

(2) *Exterior angles, or the outside angles at the vertices of a polygon* (fig. 11②).—They are generally used on traverse work when running clockwise around a closed circuit.

(3) *Deflection angles, or the exterior angles between the old line or course prolonged and the new course* (fig. 11③).—They are measured to the right or to the left and the direction should always be indicated.

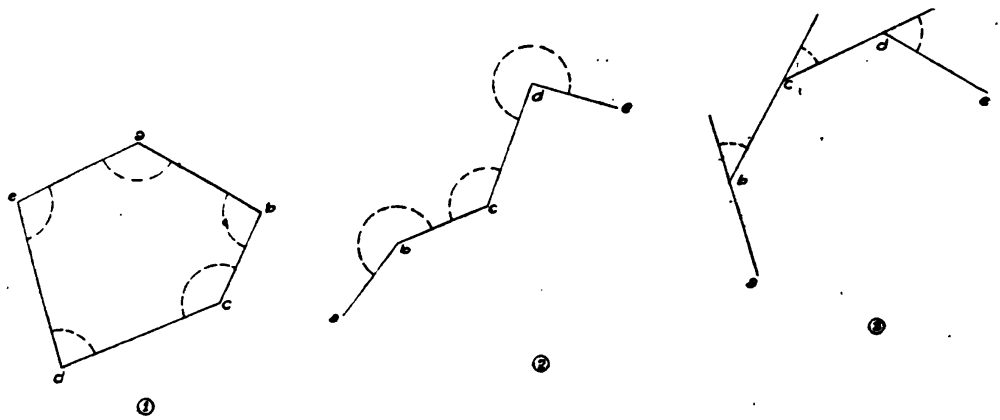


FIGURE 11.—Horizontal angles.

b. Horizontal directions are also expressed as azimuths, and angles may be measured in these terms.

49. To measure a horizontal angle.—With the instrument set up over the station at which the angle is to be read, set the zero of the vernier opposite the zero of the horizontal circle, using the upper clamp and tangent screw to bring them to coincidence. Using the lower motion, point approximately at the first object by looking over the top of the telescope. Move the telescope until the vertical cross hair is very nearly on the point, clamp the lower plate by means of the lower clamp thumb screw, and set exactly on the point by the lower clamp tangent screw. The line of sight is now on the first object. To measure the angle, loosen the upper clamp, turn the telescope to the second point, set approximately on the point, clamp the upper plate, and set the vertical cross hair exactly on the point by the upper tangent screw. The angle is then read on the vernier which

was set at zero. As a check on this reading, read the other vernier and subtract 180°; the results should be the same. One should never overrun the point in bringing the vertical cross hair upon it, because by keeping a continuous right-hand motion, all lost motion in the plates is eliminated. The verniers are read in the direction of motion and for a precise survey the readings of both are recorded.

50. Angles by repetition.—The mean of a number of measurements of an angle gives a value of the angle more nearly accurate than any single measurement.

51. To measure a vertical angle.—*a.* An angle having its two sides in the same vertical plane is a vertical angle. If one side is horizontal and the other side is above it, the angle is one of elevation; if below, it is an angle of depression.

b. Set up and level the transit, and sight upon the distant point; turn the telescope until it is approximately horizontal, clamp, and with the slow-motion screw center the telescope bubble accurately. If the vertical arc vernier reads zero, there is no index error; if not, read and note the angle for the index correction, which must be applied with proper sign to the observed vertical angle. Next sight on the distant point and read the vertical angle. To determine the angle of elevation (or depression) between two points, it is, of course, necessary to take into account the height of instrument and the height of target at the distant point.

52. To run or prolong a straight line.—*a.* To run a straight line between two points which are mutually visible, set up over one point as *A* (fig. 12) and sight on the other point *B*. This establishes the line, and any number of intermediate points may be set in this line of sight.

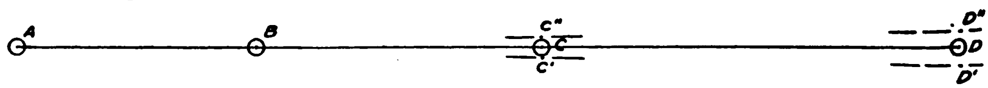


FIGURE 12.—Running or prolonging a straight line.

b. If the two points between which a straight line is desired are not mutually visible, set up as nearly as possible on the line between them and at such a point that both are visible from the instrument. Sight on one point, plunge the telescope, note how much this trial line varies from the second point, and estimate the next position for the transit. A point in the line is finally found by successive approximations. This is a slow process; to acquire aptness requires considerable practice on the part of the operator.

c. To prolong a line from two points, the method in *a* above can be used if the prolongation of the line is visible from *A*. If the

prolongation of the line is not visible from A (fig. 12), set up over B, sight at A, and plunge the telescope. The vertical cross hair will now prolong the straight line if the instrument is in adjustment, and points C and D may be set in on the continuation of the line. If the transit is not in adjustment, set out the points C' and D' on the new line, rotate the plate 180°, sight again on A, and plunge as before; setting new points C'' and D'' on the continuation of the line. Equidistant between the points C' and C'' and between D' and D'' will be found the true points C and D of the straight line.

53. Range poles.—Range poles are usually 8 or 10 feet long, round or hexagonal, and about 1 inch in diameter. They are made of wood shod with an iron point or of a steel rod or tube; they are graduated in feet, the graduations being painted alternately red and white. The range pole is used to mark a point on the ground so as to make it visible from a distance. The sharp point of the pole may be placed on the tack head in a stake. The rod is plumbed by balancing it between the finger tips of both hands, the rodman standing squarely behind it, facing the instrument. It may also be used for "lining up" or "ranging in" lines. In this case the rodman carries the pole vertically, moving right, left, backward, or forward as directed by a signal from the instrumentman.

54. Stadia.—*a.* The stadia is a device for measuring distances by reading an intercept on a graduated rod; it is used when great precision is not required. For this purpose, two additional horizontal hairs, called stadia hairs, are carried in the transit telescope on the same reticule as the cross hairs and are placed equidistant from the horizontal hair.

b. Stadia rods.—Stadia rods are usually 12 to 14 feet long, graduated to 0.05 feet, and self-reading.

c. Use of the stadia.—The transit is constructed with its lower and upper horizontal stadia hairs so placed that the intercepted part of the rod, multiplied by 100, is equal to the distance between the instrument and the point on which the stadia rod is read; for example, a reading between the upper and lower horizontal hairs of 3.45 feet on the rod is equal to 345 feet on the ground.

d. Stadia constants.—The stadia constants are K and $(c+f)$.

(1) Since it is difficult to place stadia hairs exactly, many instruments read "long" or "short." This difference is expressed by a factor called K.

(2) $(c+f)$ is a correction to be added to each stadia reading—f is the distance from the objective lens to the cross hairs and c is the distance from the objective lens to the center of the instrument.

$(c+f)$ is usually given by the instrument maker; if not, it can easily be determined by measuring along the outside of the telescope.

(3) K is determined by the following formula: $D=Ks+(c+f)$, where D is the true horizontal distance and s is the stadia distance. In determining K, several distances may be measured and the mean of the values of the several K's may be used.

e. Vertical angles.—(1) To determine the horizontal distance and difference of elevation between points by stadia, the vertical angle is usually read to the nearest minute. With the center horizontal hair set on the rod at the height of the instrument, the reading on the vertical arc will give the vertical angle. The difference of elevation may be computed by using the formula—

$$\text{Difference of elevation}=D\tfrac{1}{2}\sin 2A.$$

The horizontal distance may be computed by using the formula—

$$\text{Horizontal distance}=D\cos^2 A,$$

where D is the stadia reading corrected by the constants and A is the vertical angle.

(2) For field work, stadia tables and a device known as Cox's stadia computer are used to compute horizontal and vertical distances.

Chapter 5

BASIC SURVEY OPERATIONS

		Paragraphs
Section I.	General	55–59
II.	Traverse	60–66
III.	Resection	67–70
IV.	Long-base intersection	71–73
V.	Short-base intersection	74–79
VI.	Calculation of distances, *Y*-azimuths, and coordinates	80–81
VII.	Astronomical methods	82–84

Section I

GENERAL

	Paragraph
Methods	55
Precision and accuracy	56
Basic survey operations	57
Orientation	58
Location of a point by inspection	59

55. Methods.—The methods of survey include the use of surveying instruments and computation; the use of fire-control instruments and computation; graphic methods; and a combination of graphic methods and computation. Surveying instruments and computation usually give the most accurate results. Graphic methods are generally more rapid but less accurate than computation.

56. Precision and accuracy.—The greatest precision consistent with the time available habitually should be sought. When limited time forces the use of rapid methods, it should be remembered that there is a limit to allowable inaccuracies, and that a survey which brings too great an error into the preparation of fire is of no value. The possibilities of mistakes or blunders must also be considered. The hurried use of precise methods may cause great inaccuracies through mistakes. In survey work and the training therefor, the following should be observed:

a. Use the most precise method that time permits.

b. Even though time is pressing, a method which is not capable of producing satisfactory preparation of fire should never be employed.

c. Check all work if only by a rough method. Employ completely independent checks by different men when practicable.

d. Watch particularly the preparation of notes; these must be legible, accurate, and clear. More mistakes occur through badly kept notes than through errors in measurements or calculations.

e. In all survey work, develop methods and procedure which produce accuracy and eliminate mistakes. Enforce these methods rigidly.

f. Study methods for the *weak link.* One inaccurate step will destroy the accuracy of an otherwise precise survey.

g. Use selected men in survey sections. Remove men who do not become precise and methodical with reasonable training. *Remove the men who make mistakes.* A good survey man, like a good gunner, rarely makes a mistake.

57. Basic survey operations.—*a.* In general, basic survey operations consist of the location of points, the measurement of distances and angles, and the determination and transmission of direction. Points are located horizontally by inspection, traverse, resection, and intersection. Distances are determined by traverse (taping or stadia), by intersection (long or short base), or by computation using an auxiliary base. Direction is determined by known points or directions on the ground or by astronomical methods. Direction is transmitted by measuring or computing angles. Points are located vertically from contours, by leveling, or by computations, using distances and angles of site.

b. The basic survey operations discussed hereinafter are not necessarily separate and distinct operations. The discussion treats of the subject under the generally accepted terms: *traverse, resection, long base,* and *short base.* One of these operations may include other basic operations; for example, short-base methods may be used to determine the length of the long base.

58. Orientation.—A map, air photo, or firing chart is oriented when it is placed so that a line thereon is parallel to the corresponding line on the ground, both lines having the same direction. An angle-measuring instrument is oriented by placing its 0–3200 line along a line of known direction; or it may be oriented by setting off a given angle which corresponds to the known direction and then sighting along the line.

59. Location of a point by inspection.—If a map or photo shows the desired point or a feature very close to it, the location may be determined by eye. This method is especially applicable when using air photos.

Section II

TRAVERSE

	Paragraph
Definitions	60
Methods and personnel	61
Duties of tapeman	62
Methods of transit traverse	63
Aiming-circle and plane-table traverses	64
Adjusting traverse	65
Plotting traverse	66

60. Definitions.—*a*. A *traverse* is a series of consecutive course lines whose lengths and relative directions have been determined, thereby locating the stations with respect to each other.

(1) A *directional traverse* is a traverse which carries direction only; the distances between stations are not measured.

(2) A *closed traverse* is one which comes back to the starting point or is run to a point of known location.

(3) An *open traverse* is one which does not end at a known point.

b. *Station* is the point where the course or direction changes.

c. A *leg* is the straight line between stations.

61. Methods and personnel.—*a*. *Methods*.—(1) For a precise traverse, the transit is used. When less precise work is satisfactory, the aiming circle or the plane table may be employed.

(2) The closing of a traverse always is valuable as a check against blunders; it also permits the traverse to be adjusted. While the accuracy of the transit traverse should be sufficient for field artillery survey purposes, it should be closed and adjusted whenever time permits.

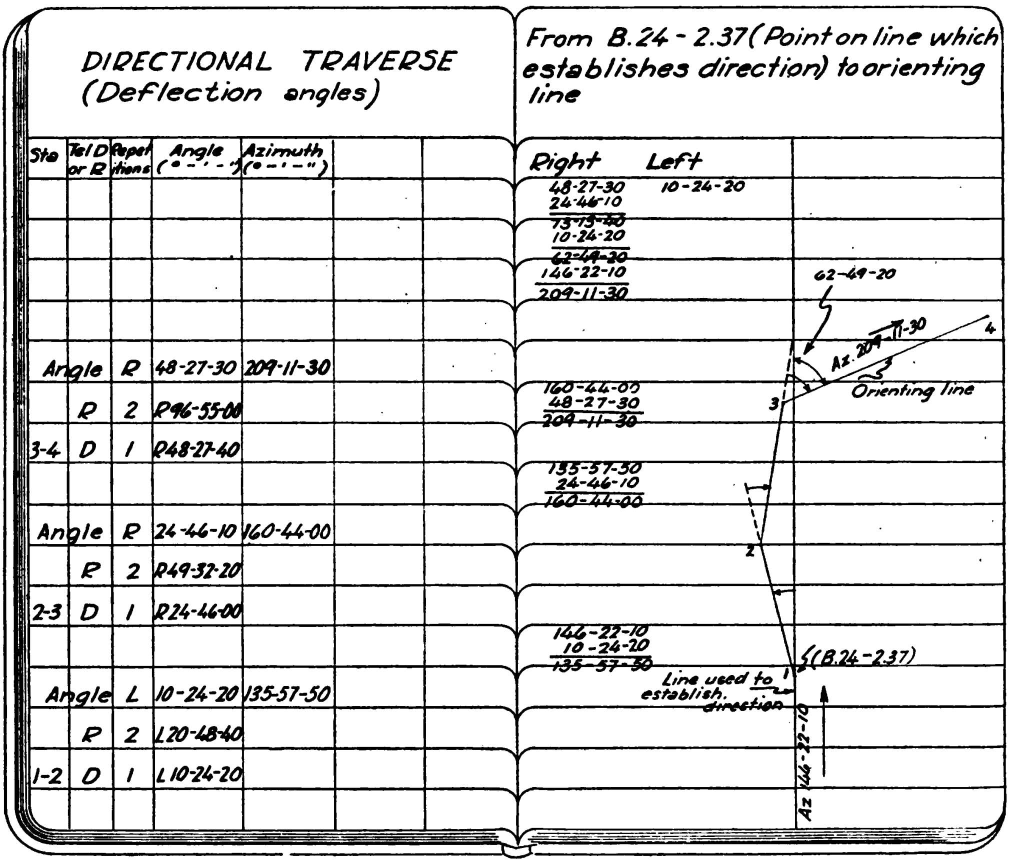
(3) In the running of a traverse, altitudes may also be determined by measuring the vertical angles between stations.

(4) Distances may be determined by taping or stadia. Taping normally is used in field artillery survey.

b. *Personnel of a traverse party*.—A traverse party consists of an instrument man in charge, a recorder who aids the instrument man, two tapemen, and two rodmen. The rodmen hold the rods (range poles) on the foresight and backsight. In case of necessity, a tapeman may perform the duty of front rodman, and the instrument man may act as his own recorder.

62. Duties of tapeman.—The distance between stations is measured in a straight line. At each station the tapemen habitually are given the direction to the next station to which measurement is made. The rear tapeman lines in the head tapeman. When the

next station is not visible because of intervening terrain, an intermediate point in line is used, or the head tapeman lines himself in with the last station. The greatest care must be taken that distances are recorded without error. As previously indicated, each tapeman keeps an independent record. In addition, the instrument man habitually paces the distance as a check against the loss of a tape-length or other mistake. In case there is disagreement or



① Directional traverse.

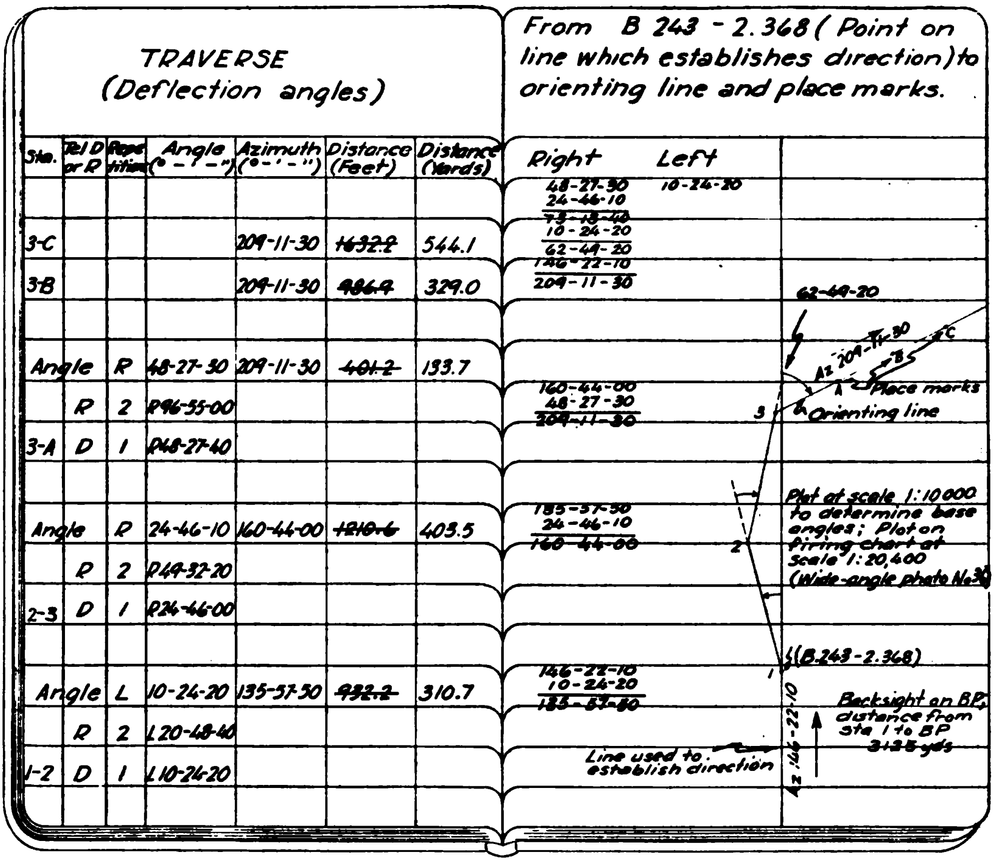
FIGURE 13.—Field notes.

doubt as to the distance, it should be retaped. Stadia readings serve as an excellent means of checking taped distances.

63. Methods of transit traverse.—*a*. The methods of running traverses may be grouped in accordance with the methods of measuring and recording the transit angles by—

(1) Deflection angles.
(2) Direct angles, exterior or interior.
(3) Azimuths.

b. The use of deflection angles is an excellent method for field artillery survey because of simplicity and the ease with which the angles may be visualized. The instrument is set up over the station, the vernier or verniers are checked, and a pointing is made on the previous station. The telescope is plunged to extend the line forward; then the upper motion is released and a deflection angle is turned to point at the new station. When the upper motion has



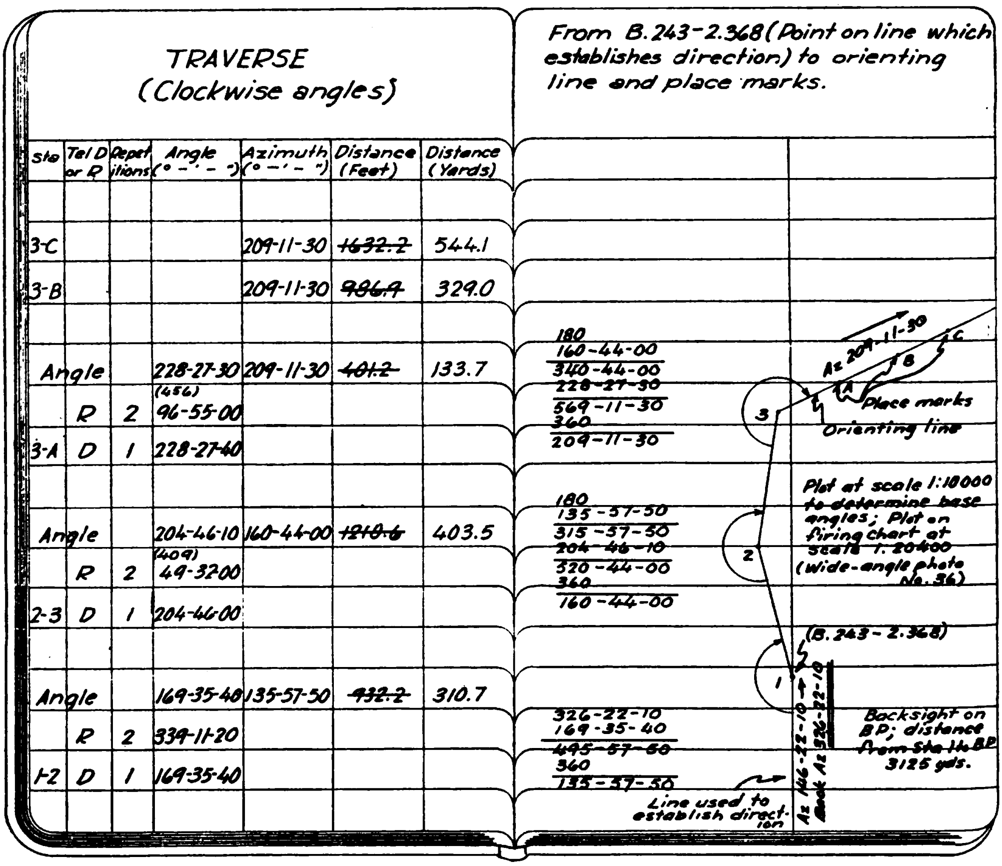
Sta.	Tel D or R	Repetition	Angle (° - ' - ")	Azimuth (° - ' - ")	Distance (Feet)	Distance (Yards)
3-C				209-11-30	~~1632.2~~	544.1
3-B				209-11-30	~~986.9~~	329.0
Angle		R	48-27-30	209-11-30	~~401.2~~	133.7
	R	2	R96-55-00			
3-A	D	1	R48-27-40			
Angle		R	24-46-10	160-44-00	~~1210.6~~	403.5
	R	2	R49-32-20			
2-3	D	1	R24-46-00			
Angle		L	10-24-20	135-57-50	~~932.2~~	310.7
	R	2	L20-48-40			
1-2	D	1	L10-24-20			

③ Traverse with deflection angles.

FIGURE 13.—Field notes—Continued.

been clamped and the pointing completed, the vernier or verniers are read. The difference between this reading and the initial reading is the deflection angle. The lower motion is then released and, with the telescope still plunged, the transit is turned until it points back to the previous station. With the lower motion again clamped, the process is repeated and the deflection angle is measured a second time. The second reading serves as a check on the first. The mean of the two measurements is used to eliminate errors due to imperfect

adjustment of the transit. For the usual field artillery survey, the readings may be limited to the *A* vernier. When special precision is desired, both verniers should be read. Added precision is attained by several readings; for example, three with the telescope direct and three with the telescope plunged. Figure 13 ① and ② are examples of field notes of traverses using deflection angles. The notes are kept on the left page of a standard transit notebook; a sketch showing the traverse is made on the right page. To assist in visualizing the


TRAVERSE
(Clockwise angles)

Sta	Tel D or R	Repetitions	Angle (° – ′ – ″)	Azimuth (° – ′ – ″)	Distance (Feet)	Distance (Yards)
3-C				209-11-30	~~1632.2~~	544.1
3-B				209-11-30	~~986.9~~	329.0
Angle			228-27-30	209-11-30	~~401.2~~	133.7
	R	2	(456) 96-55-00			
3-A	D	1	228-27-40			
Angle			204-46-10	160-44-00	~~1210.6~~	403.5
	R	2	(409) 49-32-00			
2-3	D	1	204-46-00			
Angle			169-35-40	135-57-50	~~932.2~~	310.7
	R	2	339-11-20			
1-2	D	1	169-35-40			

③ Traverse with clockwise angles.

FIGURE 13.—Field notes—Continued.

angles, the notes should be started at the bottom and run up the page. Computations of azimuths should be recorded as shown; each measured angle and the computations to determine the mean may also be recorded.

c. Running traverses by direct angles consists simply in measuring each angle directly from a backsight on a preceding station. If desired, the accuracy of measurement may be increased by repetition. Angles usually are measured in a clockwise direction. The transit

notes of a traverse made with direct clockwise angles are shown in figure 13③.

d. Traverses may be run by azimuths; this is the usual procedure for engineer surveys. When using this method, the controlling vernier reads zero when the telescope is pointed in zero direction, which normally is true north. For additional information as to this method see TM 5-235.

e. For a precise traverse, the locations of stations must be accurately marked, particularly if the legs are short. This is accomplished by setting a short 2 inch by 2 inch stake flush with the ground surface and driving a tack at the exact point. The transit is set up accurately over the tack. Tacks with cup-shaped heads should be used so that the range pole may be held in place without difficulty.

64. Aiming-circle and plane-table traverses.—The methods are generally the same as those used in transit traverses, with obvious modifications made necessary by the construction of the instruments. In these traverses, precise locating of stations, indicated in paragraph 63*e*, usually is not warranted. Closing and adjustment are particularly applicable to plane-table traverses.

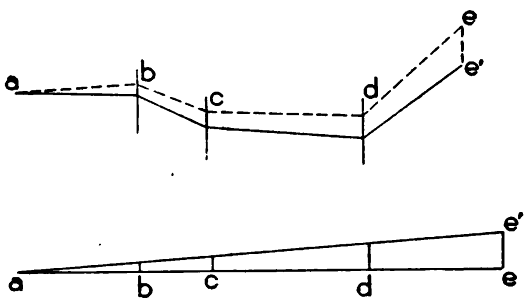


FIGURE 14.—Adjusting closing error.

65. Adjusting traverse.—In a closed traverse, if the error of closure is more than 1 percent of the total length of the traverse, the traverse should be repeated. If less than 1 percent, the traverse may be adjusted as follows:

a. In figure 14, the dotted line through points *a*, *b*, *c*, *d*, and *e* represents a closed traverse as actually made, beginning at *A* and closing on *E*, the ground locations of *a* and *e*, respectively; *ee'* is the error of closure.

b. Lay off on a straight line successively the various distances *ab*, *bc*, and so on, representing each leg of the traverse.

c. From the last point *e* draw a line *ee'* equal to the error of closure and approximately at right angles to *ae*. Draw a straight line connecting *a* and *e'*.

d. Through the points *a*, *b*, *c*, and *d*, on the straight line *ae* draw lines parallel to *ee′* cutting *ae′*. The lengths of these short lines represent the adjustments to be made on the corresponding points of the traverse.

e. On the traverse as made draw a line through each point parallel to the error of closure *ee′*. Lay off on these parallel lines the distances determined in *d* above.

f. Through these points draw the adjusted traverse (shown in solid lines).

66. Plotting traverse.—The traverse (corrected when closed) may be plotted on the chart as follows:

a. By plotting the angles and distances directly on the chart from the field notes. This method will not give precise results on a 1:20,000 scale chart.

b. If space permits, by plotting the angles and distances to a larger scale such as 1:2,000, 1:5,000, or 1:10,000; the resultant direction and distance are then plotted on the firing chart to the proper scale.

c. By computing trigonometrically, the coordinates of each station successively from its azimuth and distance (pars. 80 and 81). An arbitrary grind may be assumed, if necessary.

d. By methods of computation shown in TM 5-235.

Section III

RESECTION

	Paragraph
Definition	67
Tracing-paper method	68
Back-azimuth method	69
Bessel (Italian) method	70

67. Definition.—Resection is the locating of the occupied station by means of rays drawn from other points located on the chart or map. Angles of intersection should not be less than 300 mils. Resection is normally made with three or more points.

68. Tracing-paper method (fig. 15).—This method requires three (preferably four or five) distant visible points (*A*, *B*, and *C*) located on the map or grid as *a*, *b*, and *c*. The angles between the distant points are measured with an aiming circle and plotted on the transparent paper. The rays going to *A*, *B*, and *C* are marked for identification only. The transparent paper is moved until each ray passes through the map location of the point sighted on. The map location of the point *P* is then pricked through the tracing paper at the intersection of the rays.

69. Back-azimuth method (fig. 16).—*a. General.*—The back azimuth of a given direction is the azimuth plus (or minus) 3,200 mils. The back-azimuth method requires an accurately declinated angle-measuring instrument and three visible points located on the map.

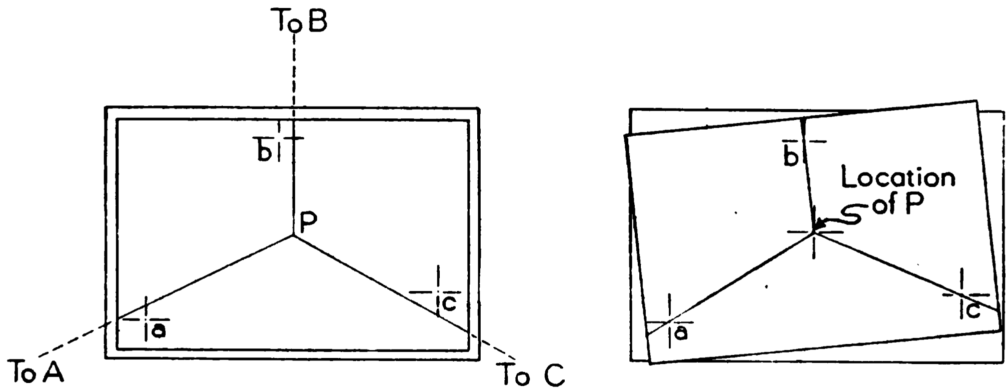
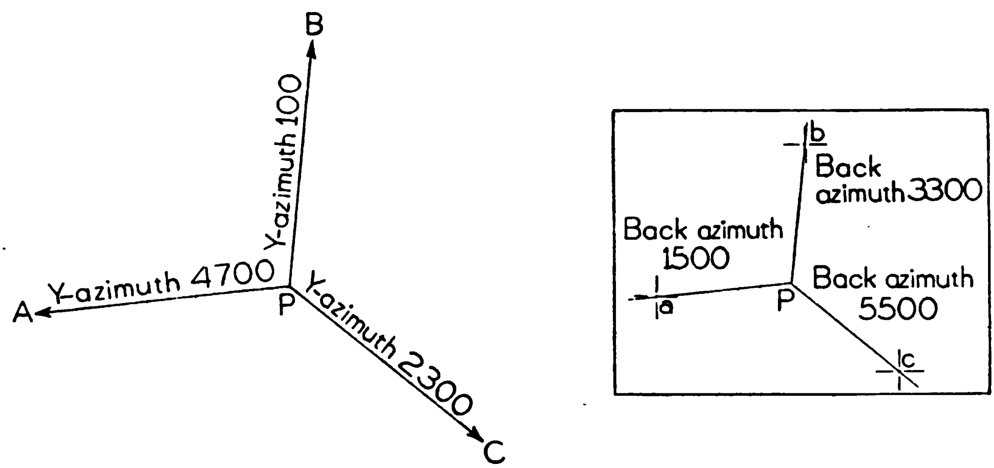


FIGURE 15.—Tracing-paper resection method.

b. Procedure.—Set up the declinated instrument at the point to be located and measure the *Y*-azimuth of each of the three distant points. Find the back azimuth by adding (or subtracting) 3,200 mils to each *Y*-azimuth. Through each plotted point, draw a ray with the proper



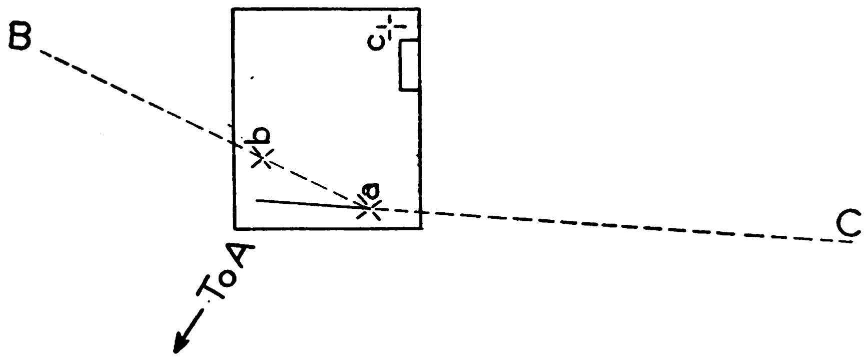
① Back azimuth. ② Plotting back azimuth.

FIGURE 16.—Back-azimuth resection method.

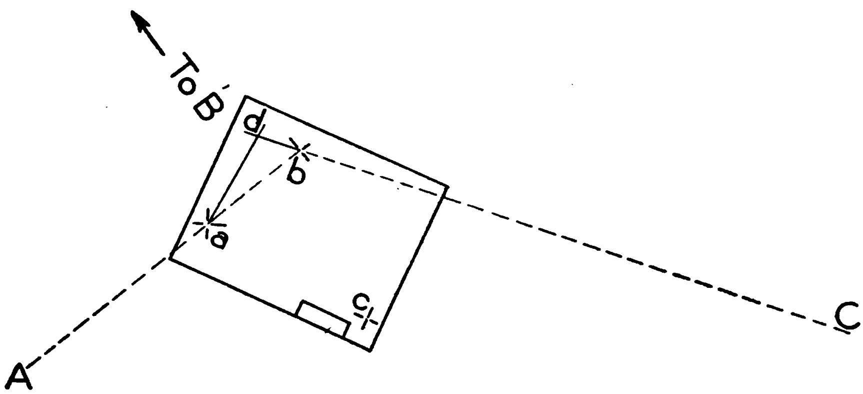
back azimuth. The intersection of the rays is the location of the station *P*.

c. Accuracy.—The accuracy of location of the point depends upon the accuracy with which the declination constant of the instrument has been determined with respect to the chart used. It is the only

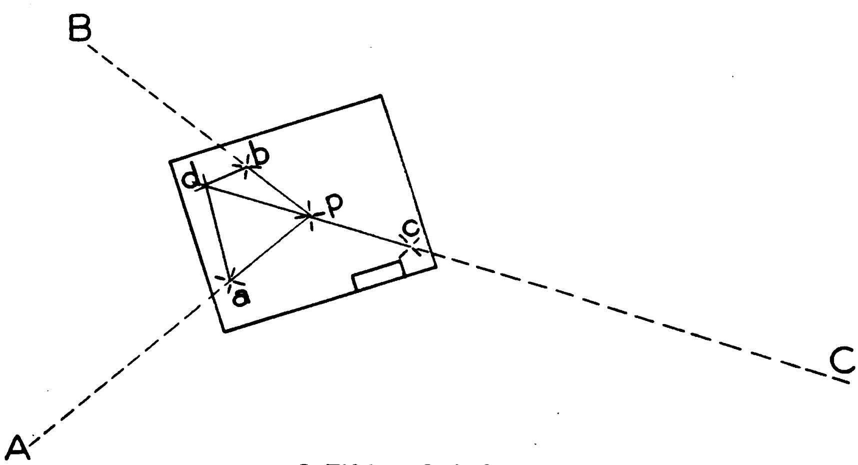
method which can be used when P is on the circumference of the circle passing through A, B, and C.



① First and second steps.



② Third and fourth steps.



③ Fifth and sixth steps.

FIGURE 17.—Three-point resection, Bessel (Italian) method.

70. Bessel (Italian) method (figs. 17 and 18).—*a. General.*—The first steps orient the board; the last step locates the occupied

station *P*. In figure 17, sights are shown by dotted lines; lines drawn on the board by full lines.

b. Procedure.—(1) Select three points, *A*, *B*, and *C*, plotted on the board as *a*, *b*, and *c*; *c* is the most distant point. No preliminary attempt is made to orient the board but it should be leveled carefully.

(2) Sight along *ab* to *B* and clamp the board (fig. 17①).

(3) Sight from *a* to *C* and draw the ray *aC*, extended if necessary, through *a* (fig. 17①).

(4) Unclamp the board, sight along *ba* to *A*, and clamp the board (fig. 17②).

(5) Sight from *b* to *C* and draw the ray *bC*, intersecting *aC* at *d* (fig. 17②).

(6) Draw *dc* (fig. 17③). The occupied station *p* is on the line *dc*. Unclamp the board, place the alidade along the line *dc*, sight on *C*, and clamp the board. Be sure that the points on the board bear the proper relation to the points on the ground. The board is now oriented.

(7) Locate *p* by resection using the points *A* and *B*. The intersection of *Aa* and *Bb* with the line *dc*, extended if necessary, is the location of *p* on the board. Ordinarily there is no triangle of error. Check by sighting on a fourth point if possible.

c. Precautions.—(1) The points should be selected so that *d* will fall on the board. The approximate location of *d* may be determined as indicated in (2) below (fig. 18).

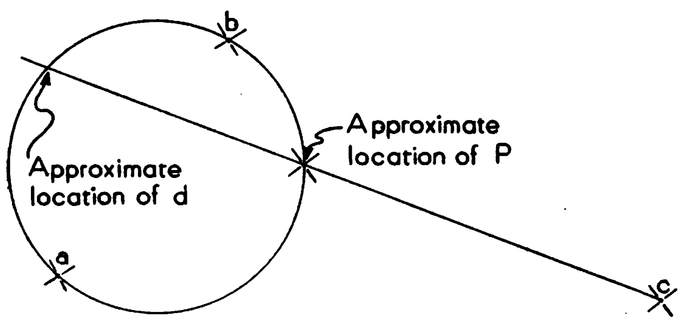


FIGURE 18.—Location of point *d*.

(2) Locate *p* roughly and approximate a circle through *a*, *b*, and *p*. *d* is the intersection (other than *p*) of a ray *pc* with the circle. *d* will be off the board if *p* is on or near the line *ab*.

(3) The ray *dc* must be long enough to give an accurate orientation. This is the case with *p* inside the triangle *abc*, and also with *p* outside the triangle when the circumference of the circle is not close to *c*.

(4) The method requires a favorable location of *P* relative to the triangle *ABC*. When this does not exist, the tracing-paper or back-azimuth methods may be used.

d. With an aiming circle or transit.—The Bessel (Italian) method of resection may also be done by measuring the angles *CaB* and *CbA* (fig. 17) with an instrument set up at *P* and doing the plotting indicated in figure 17 later in a sheltered location. It will be noted that these angles are, respectively, the same as *CpB* and *CpA*.

Section IV

LONG-BASE INTERSECTION

	Paragraph
Definitions	71
Advantages and disadvantages	72
Procedure	73

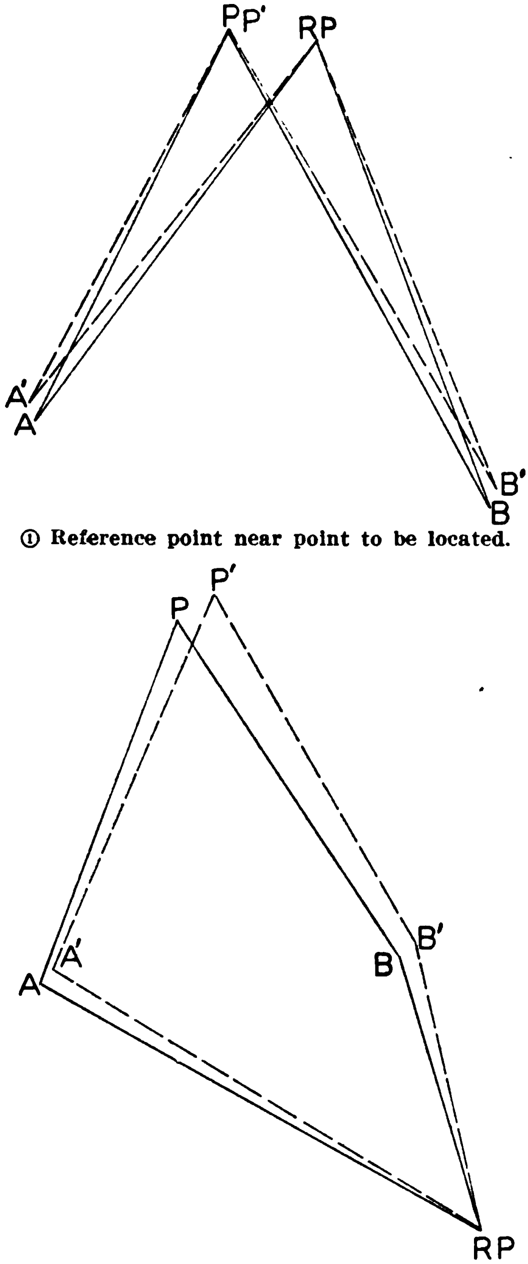
71. Definitions.—When a base is sufficiently long to permit the use of graphic methods in the location of a point by intersection, it is termed a *long base*. To permit the use of graphic methods, the angle of intersection of the rays from the ends of the base to the desired point must be at least 500 mils. The graphic methods normally used with the long base are known as *long-base methods*. When great accuracy is desired, computation may be employed with a long base, but such accuracy normally is not required.

72. Advantages and disadvantages.—The primary advantage the long base is the rapidity with which the point may be plotted after the necessary angles have been measured. The chief disadvantage is the difficulty of identifying points from two stations separated by several thousand yards. The determination of the location of the ends of the base may at times be difficult.

73. Procedure.—To determine the direction of the rays which intersect at the point, angles must be measured from both ends of the base with respect to the opposite end of the base, or with respect to some known reference point accurately located on the chart and identified on the ground. When the point to be located is accessible, the measurement of the angle at this point may be used for computing the angle at one end of the base. The accuracy with which the base ends must be located depends on the method used. The three general cases are as follows:

a. Using the base for reference.—When no satisfactory reference point can be identified on both the chart and the ground, the measurements are made with respect to the base. In such case, the ends

must be located by accurate survey, preferably with respect to the two control points used to establish direction in laying the batteries



① Reference point near point to be located.

② Reference point distant from point to be located
AB is the base. *A, B, P,* and *RP* represent correct locations.
A', B', and *P'* represent locations as actually plotted.

FIGURE 19.—Long-base methods, using reference point.

(chapter 7). In order to use the base for reference, each end must be visible from the other, or intervening visible points must be located and marked.

b. Reference point near the desired point.—When the reference point is near the desired point, the ends of the base may be located by inspection or short traverse from some nearby identifiable point. In this case, small errors in locating the ends of the base will have a negligible effect on the accuracy of the location of the desired point (fig. 19①).

c. Reference point distant from the desired point.—When a reference point cannot be selected near the point to be located, the ends of the base must be located accurately (fig. 19②) since small errors may be amplified when plotting the rays to the desired point. The smaller the angle of intersection the more accurate must be the locations of the ends of the base.

SECTION V

SHORT-BASE INTERSECTION

	Paragraph
Short-base methods	74
Solution of right triangle	75
Solution of oblique triangle	76
Procedure followed in locating a point by computation	77
Determination of length of base	78
Determination of distance to points in battalion area	79

74. Short-base methods.—*a. General.*—Long-base graphic methods normally are too inaccurate when the angle of intersection of the rays is less than 500 mils. In this case, the desired point must be located by solving the triangle which it forms with the base. The procedure in general is to compute the distance to the desired point from a known point and plot it by means of the computed distance and a measured direction, that is, by polar coordinates.

b. Advantages.—As compared to the long base, the short base has many advantages, including ease of identification of points from both ends, less time consumed in moving from one end to the other, terrain more often favorable, and at times greater accuracy.

c. Procedure.—The procedure involved includes the selection of a base, the determination of its length, the measurement of angles at the ends of the base, the solution of the triangle, and the plotting of the point. If the point to be located is accessible, the angle at this point and the angle at one end of the base should generally be used because more accurate results are usually obtained by this method.

75. Solution of right triangle (fig. 20).—For computing the legs and angles of a right triangle, the following formulas are used:

$$a^2+b^2=c^2.$$

$$\text{Sin } A=\frac{a}{c}.$$

$$\text{Cos } A=\frac{b}{c}.$$

$$\text{Tan } A=\frac{a}{b}.$$

76. Solution of oblique triangle (fig. 21).—For computing the sides and angles of an oblique triangle, the following formulas are used:

Angle $C=180°-$(angle $A+$angle B).
Angle $C=3200$₥$-$(angle $A+$angle B).

$$\frac{a}{\sin A}=\frac{b}{\sin B}=\frac{c}{\sin C}.$$

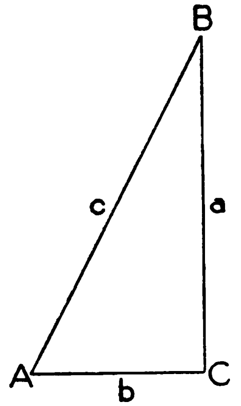


FIGURE 20.—Right triangle.

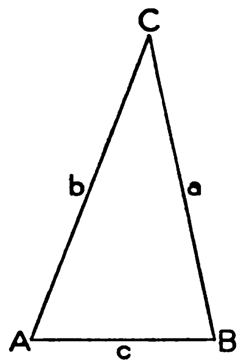


FIGURE 21.—Oblique triangle.

77. Procedure followed in locating a point by computation.—Given the point A which can be occupied; it is desired to locate the point C.

a. Procedure.—(1) From A, and as nearly at right angles to AC as practicable, a base AB is laid off, the length of which must be accurately determined. If the transit is used the length of the base must be such as to give an angle of intersection at C of at least 100 ₥. If the aiming circle is used the base must be of such length as to give an angle of intersection of at least 150 ₥.

(2) The base AB, of suitable length, having been established, an instrument is set up at A and the angle CAB is read. An instrument is set up at B and the angle CBA is read. Three cumulative measurements of each of these angles are preferable; the mean is used as the correct value.

(3) From figure 21, it can be seen that angle C=3200 $\not{m}$ − (angle A+angle B).

$$\frac{b}{\sin B}=\frac{c}{\sin C} \text{ or } b=c\times\frac{\sin B}{\sin C}$$

The length c is known, being the base AB. The values of angle B and angle C are known. The sines of these angles may be found from the table of natural functions in the firing tables. Therefore the value of b may be obtained arithmetically or by logarithmic computation.

(4) If a transit is used, a slide rule, graduated for degrees and minutes, may be used as a check against large errors.

(5) The value of b, which is the distance AC, having been determined, C may be plotted by reading at A the angle to C from a known reference point and plotting C at the computed distance from A on this direction line.

b. Example.—Assuming values as shown in figure 22, the procedure is as follows:

$$\text{Angle } A=1522\ \not{m}$$

$$\text{Angle } B=\frac{1499\ \not{m}}{3021\ \not{m}}$$

$$\text{Angle } C=3200-3021=179\ \not{m}$$

$$b=c\times\frac{\sin B}{\sin C}$$

$$=650\times\frac{\sin 1499\ \not{m}}{\sin 179\ \not{m}}$$

From firing tables: sin 1499 $\not{m}$=.99509; sin 179 $\not{m}$=.17483

$$b=650\times\frac{.99509}{.17483}=3{,}700 \text{ yards}$$

If point C is 742 $\not{m}$ left of a reference point, the point C is then plotted 742 $\not{m}$ left of the reference point and at a distance from A of 3,700 yards (fig. 23).

78. Determination of length of base.—The length of the base can be determined in any one of the ways listed below. It is of *extreme importance that the length of the base be determined with great accuracy*, since small errors in the length of the base cause comparatively large errors in the computed distance.

a. Taping.—Whenever the nature of the terrain permits, the length of the base should be determined by taping. This is the most accurate method of determining short distances and should be used whenever practicable.

b. By computation using an auxiliary base.—The length of the base may often be determined by computation when the nature of the terrain prevents taping or makes taping inaccurate. The length

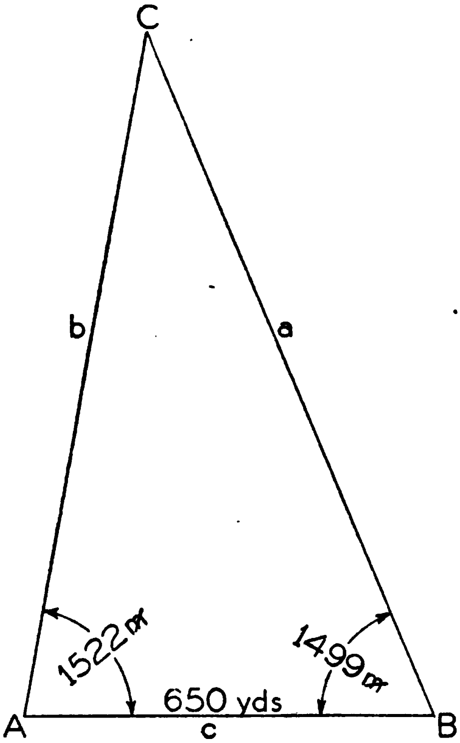


FIGURE 22.—Solution of oblique triangle.

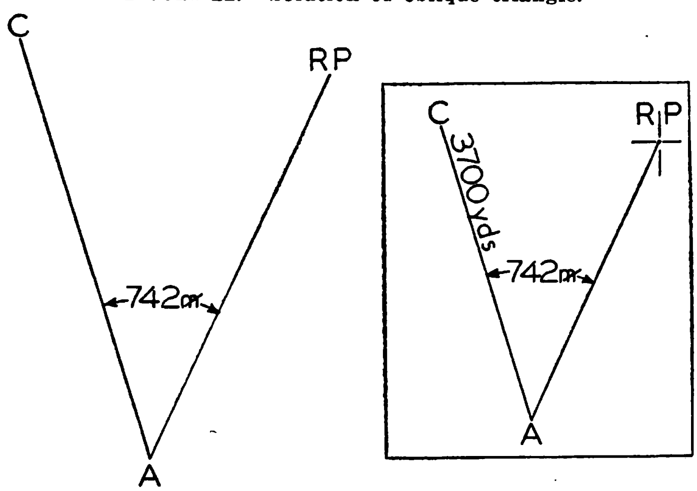


FIGURE 23.—Plotting a point by computed range and measured direction.

of the base may be determined by computation in two ways as follows:

(1) *With an auxiliary base established at right angle to base* (fig. 24).—The right-angle method is faster and more accurate than

establishing the auxiliary base at an oblique angle to the base. The auxiliary base may be established at either end of the base. The length of the auxiliary base should be sufficient to make the angle subtended by the auxiliary base greater than 100 mils when a transit is used and greater than 150 mils when an aiming circle is used. With multiple readings and careful work, an error of 1 yard per thousand for the transit and 2 yards per thousand for the aiming

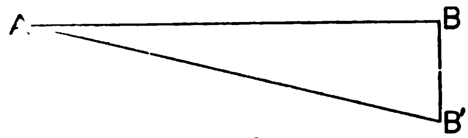


FIGURE 24.—Auxiliary base established at right angle to base.

circle should not be exceeded. The procedure is as follows: An instrument is set up at B and laid on A. An angle of 1600 is turned off. In this direction, an auxiliary base BB' is laid off. With an instrument at A, the angle BAB' is read. From figure 24, it can be seen that $\tan A = \frac{BB'}{AB}$ or $AB = \frac{BB'}{\tan A}$. BB' is known, being the auxiliary base established. Tan A can be found from the table of natural functions in the firing tables or in TM 5-236. Therefore AB may be found by long division or by logarithmic computation.

Example: Suppose $BB' = 100$ yards and angle $A = 157$ ₥.

Then, $AB = \frac{100}{\tan 157 \text{ ₥}}$.

From firing tables, $AB = \frac{100}{.15537} = 644$ yards.

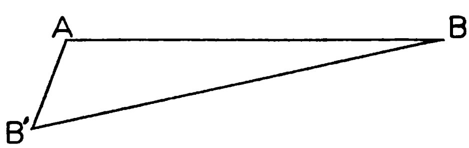


FIGURE 25.—Auxiliary base established at oblique angle to base.

(2) *With auxiliary base established at oblique angle to base* (fig. 25).—This method should be used only when the preceding method cannot be used. As before, the auxiliary base may be established at either end of the base. The procedure is exactly the same as that explained in paragraph 77.

79. Determination of distance to points in battalion area.—Time and labor can often be saved in determining the distance to

points in the battalion area, such as place marks, battery positions, observation posts, etc., by using the methods of computation described in the preceding paragraphs.

SECTION VI

CALCULATION OF DISTANCES, *Y*-AZIMUTHS, AND COORDINATES

	Paragraph
Distances and Y-azimuths from coordinates	80
Calculation of coordinates	81

80. Distances and *Y*-azimuths from coordinates.—*Example.*—The coordinates of two points being known, to find the distance between the points and the *Y*-azimuth of the line joining them (fig. 26).

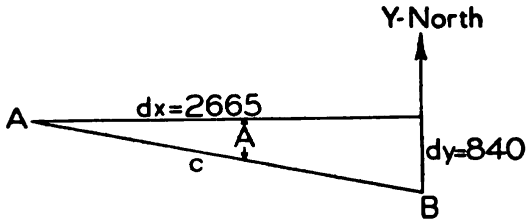


FIGURE 26.—Calculation of distances and Y-azimuths.

Point *A*—(815.475–1267.430)
Point *B*—(818.140–1266.590)

818.140	1267.430
815.475	1266.590
2665 = dx (x-difference)	840 = dy (y-difference)

a. Using logarithms—

$$\text{Tan } A=\frac{dy}{dx}=\frac{840}{2665}$$

Log tan A = log 840 − log 2665
Log 840 = 2.92428
Log 2665 = 3.42570

Log tan A = 9.49858 − 10
A = 17°29′.7, or 311 ₥ (1′ = .2963 ₥)

Computation using cosine:

$$\operatorname{Cos} A=\frac{2665}{c}$$

$$c=\frac{2665}{\cos A}$$

$\operatorname{Log} c=\log 2665-\log \cos A$
$\operatorname{Log} 2665 \quad =3.42570$
$\operatorname{Log} \cos A=9.97943-10$

$\operatorname{Log} c \quad =3.44627$
$c=2794.3$ yards

Computation using sine:

$$\sin A=\frac{840}{c}$$

$$c=\frac{840}{\sin A}$$

$\operatorname{Log} c=\log 840-\log \sin A$
$\operatorname{Log} 840 \quad =2.92428$
$\operatorname{Log} \sin A=9.47802-10$

$\operatorname{Log} c \quad =3.44626$
$c=2794.2$ yards

By inspection, the Y-azimuth of the line AB is $90°+17°29'.7=107°29'.7$ or 1600 m̸+311 m̸=1911 m̸. (1 mil=0.0563° or 3'.375.)

b. Using natural functions—

$$\operatorname{Tan} A=\frac{dy}{dx}=\frac{840}{2665}=.3152$$

Therefore, $A=311$ mils. (Table of natural functions in firing tables or in TM 5-236.)

$$\operatorname{Cos} A=\frac{2665}{c} \qquad \sin A=\frac{840}{c}$$

$$c=\frac{2665}{\cos A}=\frac{2665}{.9538} \qquad c=\frac{840}{\sin A}=\frac{840}{.3006}$$

$c=2794.1$ yards $\qquad c=2794.4$ yards

c. The distance also may be determined by the formula $c=\sqrt{a^2+b^2}$.

81. Calculation of coordinates.—*a. Example.*—Knowing the coordinates of a point and the Y-azimuth and distance from this

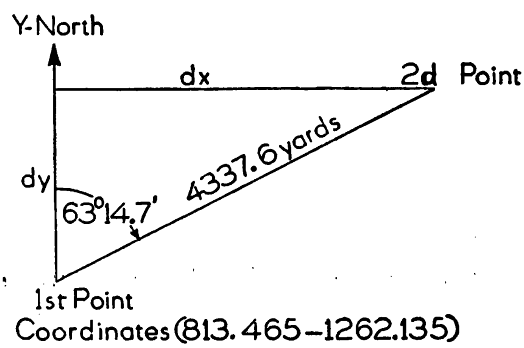


FIGURE 27.—Solution of right triangle.

point to a second point, to calculate the coordinates of the second point (fig. 27).

$$\text{Sin } 63° \ 14'.7 = \frac{dx}{4337.6}$$

$dx = 4337.6 \times \sin 63° \ 14'.7$
Log 4337.6 $= 3.63725$
Log sin 63° 14′.7 $= 9.95082 - 10$

Log dx $= 3.58807$
dx $= 3873.2$ yards

$$\text{Cos } 63° \ 14'.7 = \frac{dy}{4337.6}$$

$dy = 4337.6 \times \cos 63° \ 14'.7$
Log cos 63° 14′.7 $= 9.65339 - 10$
Log 4337.6 $= 3.63725$

Log dy $= 3.29064$
dy $= 1952.7$ yards

Hence, the coordinates (to the nearest yard) of the second point are—

$$X = 813.465 + 3.873 = 817.338$$
$$Y = 1262.135 + 1.953 = 1264.088$$

After determining dx and dy, care should be taken to determine whether to add or subtract these values from the respective coordinates of the known point. A rough figure like the one above will be found most helpful.

b. A standardized method of computation is given in paragraph 13, FM 6-120.

Section VII

ASTRONOMICAL METHODS

Paragraph
General 82
Determination of true north by rapid methods 83
Simultaneous observations 84

82. General.—*a.* Direction may be determined or transmitted by astronomical methods. With battle maps, since the variation between true and Y-north is indicated on the map, the determination of true north permits the laying on any desired Y-azimuth; a check is furnished by the Y-grid lines. With air photos, direction may be transmitted from one point to another by determining true north at each point and by recording at one point the true azimuth of a line identifiable on the photo. Direction may be transmitted in a similar manner by simultaneous observations on a star.

b. True north usually is determined by an observation on Polaris; the sun also may be used. Because of its comparatively slow movement, Polaris is particularly suitable for simultaneous operations. When the time is accurately synchronized, other stars are satisfactory.

c. A precise determination of the true meridian is not often required in field artillery survey. Simpler and more rapid methods usually produce satisfactory accuracy. For precise astronomical methods see TM 5-235.

83. Determination of true north by rapid methods.—*a.* The elongation of Polaris may be closely determined by the position of the star Alkaid at the end of the handle of the Big Dipper (figs. 28, 29, and 30). The maximum elongation of Polaris, as given in table I, multiplied by the cosine of the angle between the horizontal and

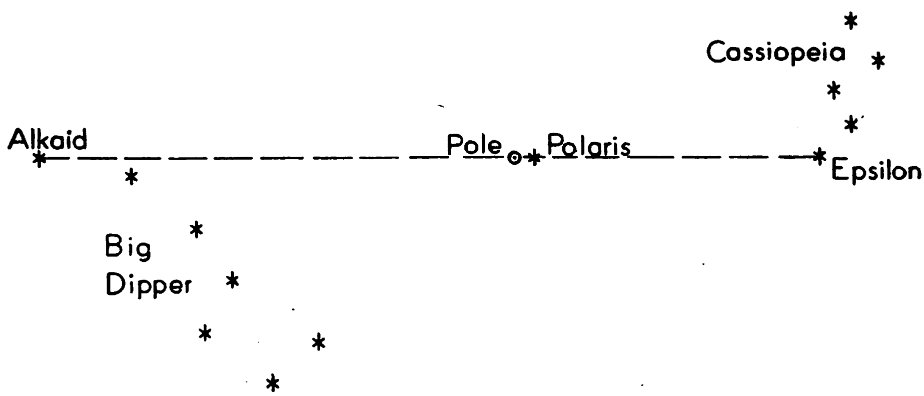


FIGURE 28.—Relative positions of the northern constellations, the Big Dipper and Cassiopeia, when Polaris is at maximum elongation (east).

the line Polaris-Alkaid (fig. 30), gives the elongation of Polaris at the time the observation is taken. The tangent of this angle is v/h where v and h are, respectively, the vertical and horizontal angles between Alkaid and Polaris; the cosine may be readily determined, knowing the tangent. The elongation of Polaris is always on the side of the pole opposite to Alkaid. If Alkaid is obscured, the star Epsilon in Cassiopeia may be used in an identical manner; the elongation is always on the same side as Epsilon.

b. Greater accuracy is obtained if the observation is made when Alkaid is near its maximum easterly or westerly elongation. The greatest error occurs when Alkaid is directly above or below Polaris, because the alinement of Alkaid, the pole, and Polaris is not exact. The error, however, is small and does not exceed one mil ($3\frac{3}{8}'$) for positions south of latitude 76° N., and, when using Epsilon, for positions south of latitude 53° N.

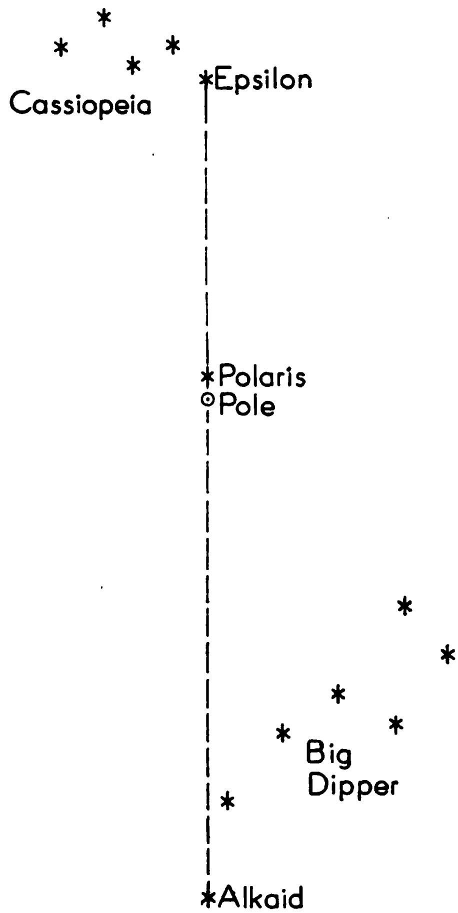


FIGURE 29.—Relative positions when Polaris is on the meridian.

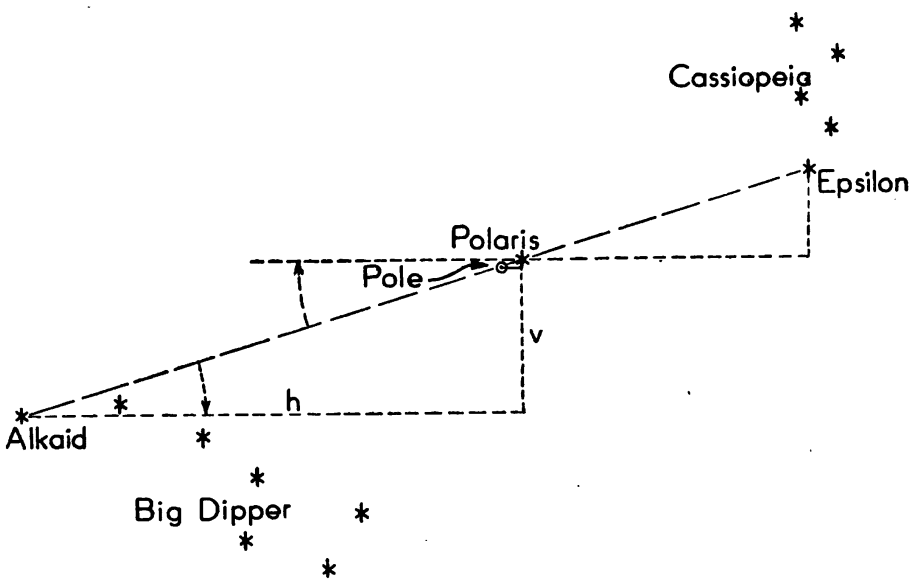


FIGURE 30.—Relative positions when Polaris is between maximum elongation (east) and meridian.

TABLE I.—*Azimuths of Polaris at elongation for the years 1940–50*

Latitude	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
25	1 7.6	1 7.3	1 7.0	1 6.7	1 6.4	1 6.1	1 5.7	1 5.3	1 5.0	1 4.6	1 4.2
26	8.2	7.9	7.6	7.3	7.0	6.6	6.3	5.9	5.5	5.1	4.8
27	8.8	8.5	8.2	7.9	7.5	7.2	6.8	6.5	6.1	5.7	5.3
28	9.4	9.1	8.8	8.5	8.2	7.8	7.4	7.1	6.7	6.3	5.9
29	10.1	9.8	9.5	9.2	8.8	8.5	8.1	7.7	7.3	6.9	6.5
30	10.8	10.5	10.2	9.8	9.5	9.1	8.8	8.4	8.0	7.6	7.2
31	11.5	11.2	10.9	10.6	10.2	9.9	9.5	9.1	8.7	8.3	7.9
32	12.3	12.0	11.7	11.3	11.0	10.6	10.2	9.8	9.4	9.0	8.6
33	13.1	12.8	12.5	12.1	11.8	11.4	11.0	10.6	10.2	9.8	9.4
34	13.9	13.6	13.3	13.0	12.6	12.2	11.8	11.4	11.0	10.6	10.2
35	14.8	14.5	14.2	13.8	13.5	13.1	12.7	12.3	11.9	11.5	11.1
36	15.8	15.4	15.1	14.8	14.4	14.0	13.6	13.2	12.8	12.4	11.9
37	16.8	16.4	16.1	15.7	15.4	15.0	14.6	14.1	13.7	13.3	12.9
38	17.8	17.5	17.1	16.8	16.4	16.0	15.6	15.1	14.7	14.3	13.9
39	18.9	18.5	18.2	17.8	17.4	17.0	16.6	16.2	15.8	15.3	14.9
40	20.0	19.7	19.3	19.0	18.6	18.2	17.7	17.3	16.9	16.4	16.0
41	21.2	20.9	20.5	20.1	19.7	19.3	18.9	18.5	18.0	17.6	17.1
42	22.5	22.1	21.8	21.4	21.0	20.6	20.1	19.7	19.2	18.8	18.3
43	23.8	23.5	23.1	22.7	22.3	21.9	21.4	21.0	20.5	20.0	19.6
44	25.2	24.9	24.5	24.1	23.7	23.2	22.8	22.3	21.9	21.4	20.9
45	26.7	26.3	25.9	25.5	25.1	24.7	24.2	23.7	23.3	22.8	22.3
46	28.2	27.9	27.5	27.1	26.6	26.2	25.7	25.2	24.8	24.3	23.8
47	29.9	29.5	29.1	28.7	28.3	27.8	27.3	26.8	26.3	25.8	25.3
48	31.6	31.2	30.8	30.4	30.0	29.5	29.0	28.5	28.0	27.5	27.0
49	33.4	33.0	32.6	32.2	31.7	31.3	30.8	30.3	29.8	29.2	28.7
50	1 35.4	1 35.0	1 34.5	1 34.1	1 33.6	1 33.2	1 32.6	1 32.1	1 31.6	1 31.1	1 30.6

Corrections for middle of months

For middle of—	Correction
	′
Jan	−0.5
Feb	−0.4
Mar	−0.3
Apr	−0.1
May	+0.1
June	+0.2
July	+0.2
Aug	+0.1
Sept	−0.1
Oct	−0.3
Nov	−0.6
Dec	−0.8

These data may be secured annually from the current Nautical Ephemeris or other similar source.

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c. Figures 28, 29, and 30 show the heavens in the region of Polaris. Figure 30 shows the horizontal and vertical angles, *h* and *v*, between Polaris and Alkaid.

d. In any general locality, and for a limited period such as a month, the true azimuths of Polaris at intervals during the night may be tabulated and published. It would then be necessary to sight on Polaris only; the ratio v/h would not be needed.

84. Simultaneous observations.—*a.* Simultaneous observations have the advantage that no computation is required because the azimuth is referred to the position of Polaris at the time of observation. Prearrangement is necessary as the observations must be taken at the prescribed time. As a check against mistakes and to insure satisfactory results if one observation fails, the simultaneous observations usually should be made three times at prescribed hours.

b. The simultaneous observations are used to transmit direction from one point to another; the purpose is similar to that of a directional traverse. If two points, identifiable on the map or photo and the ground, have been selected to establish direction, an instrument may be set up at one of them and the azimuth to the other with respect to Polaris may be determined at the prescribed time. The azimuth of this line is then reported to the other observers, who have already taken their readings at the specified time and have determined the azimuth of some line staked out on the ground, for example, the orienting line. The direction of this line, with relation to the map or photo, is now known. (See example 8, par. 144*d.*)

CHAPTER 6

AIR PHOTOGRAPHS

		Paragraphs
SECTION I.	General	85-86
II.	Tilt, relief, direction, and scale	87-89
III.	Mosaics	90-93
IV.	Restitution	94-97

SECTION I

GENERAL

	Paragraph
Use	85
Types of air photos	86

85. Use.—*a.* Air photos are of great value to the Field Artillery in reconnaissance, in the construction of firing charts, and in designating targets. Certain types of air photos, if large enough, may be used as firing charts and as a means of tying together all artillery emplaced on the photo and of tying together the artillery and the target area. When maps are used, air photos to supplement the map are essential. When a wide-coverage photo is used as the firing chart, smaller air photos giving greater detail are desirable.

b. For complete details on reading and interpreting air photos, refer to FM 21-25, FM 21-26, FM 30-21, and TM 5-230.

86. Types of air photos.—Air photos for military purposes are of the following types:

a. Verticals.—A *vertical* is an air photo taken with the camera plate (film) as nearly horizontal as practicable. The vertical air photo shows the terrain in much the same relation as does a map. Verticals should habitually be taken in a series of overlapping photos for general and special intelligence and as a fire-control accessory for field artillery. Unless the series of overlapping photos includes both position and target areas, considerable survey is needed to tie together the two areas. Verticals are classified as normal and wide-angle, depending on the angle of view. The normal vertical is taken with a longer focal length and a smaller angle of view. The wide-angle vertical is taken with a shorter focal length and a larger angle of view; this angle is approximately 70° across the square dimension of the photo and approximately 90° across the diagonal. The normal

vertical, covering less area, shows more detail and is an excellent intelligence photo. The wide-angle vertical, covering more area, is suitable as a firing chart.

b. Obliques.—An *oblique* is an air photo taken with the camera plate (film) inclined to the horizontal. Obliques are useful in studying the relative altitude of terrain features, in designating targets, in conducting observed fires, and for tactical and intelligence purposes. An oblique must be rectified to the horizontal, either when printed or by graphic restitution, before it can be used for measuring horizontal distances directly. Relief distortions are appreciable. For this reason obliques are of little value to the Field Artillery in constructing firing charts.

c. Composites.—A *composite* is made from prints of a multiple-lens camera; those from the oblique chambers being rectified into the same

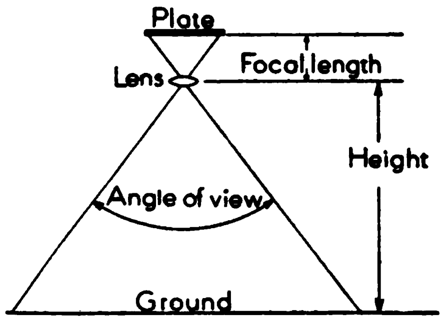


FIGURE 31.—Relation of photo to ground.

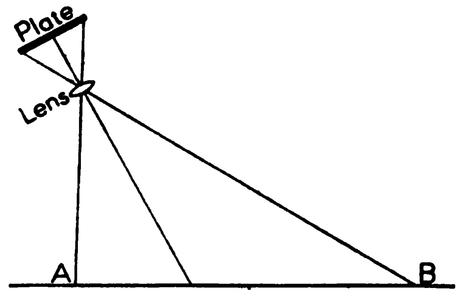


FIGURE 32.—Effect of tilt.

plane as that of the central vertical chamber. The composite is thus similar to a vertical of very wide angular coverage (approximately 140°). Relief distortion is comparatively large in the wing photos.

SECTION II

TILT, RELIEF, DIRECTION, AND SCALE

	Paragraph
Relation of photo to ground	87
Direction	88
Scale	89

87. Relation of photo to ground.—*a. General.*—If a flat piece of terrain be photographed by a level camera, the result is a perfect map in all planimetric detail (fig. 31). However, the vertical air photo is subject to distortion of detail due principally to tilt of the camera and to relief of the terrain photographed. Other elements may cause minor distortions which, however, are negligible for artillery purposes.

b. Tilt.—If the camera is not level at the moment the photo is made, the scale will not be uniform. In figure 32 it is evident that a horizontal line of certain length near *A* will appear greater on the photo than a line of the same length near *B*, since *A* is nearer the camera than *B*. When the tilt is small, which is the case in a carefully made photo, the resulting errors are negligible for artillery work. In a series of overlapping photos taken on a single flight,

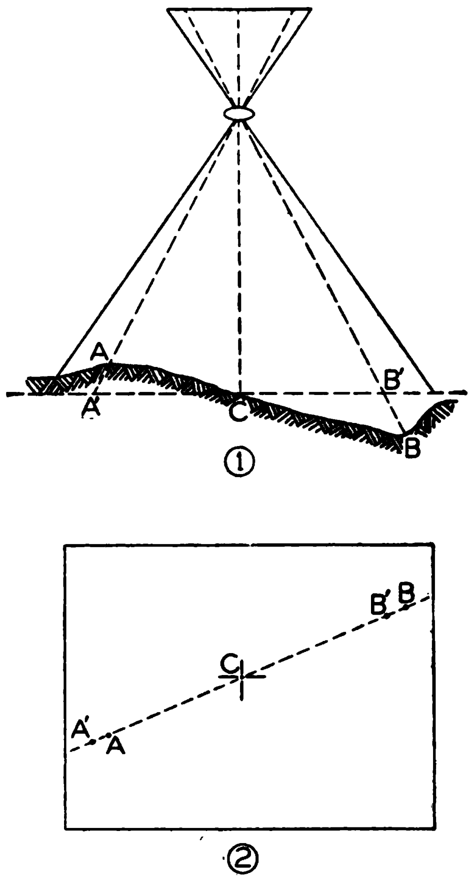


FIGURE 33.—Displacement due to relief of ground.

excessive tilt of one photo is indicated if its center varies greatly from the center line of the other photos of the series.

c. Relief.—A most important source of error is relief. Considering figure 33① as any vertical section through the axis of the lens, it is seen that *C* will be recorded in its true position, the center of the photo, regardless of its altitude. With reference to a horizontal datum plane through *C*, the object *A* at a greater altitude will record as an object located at *A′*; similarly *B* will record as at *B′*. These displacements are radial from or toward the center,

as shown in figure 33②. For a given altitude of the airplane, the amount of displacement varies directly as the horizontal distance from C and the height above or below C. Note that the directions of the radial lines CA and CB are not changed by the displacements of A and B. The relief distortion of any particular point varies inversely as the altitude of the airplane. For photographs taken at approximately 20,000 feet above the average ground level, the relief distortion with reference to any given datum plane is 5 yards per 100 feet above or below that plane for each 1,000 yards out from the focal center; for photographs taken at 30,000 feet, the distortion is 3⅓ yards per 100 feet. Table II gives the distortion for photos taken at 10,000 feet, 20,000 feet, and 30,000 feet.

TABLE II.—*Relief distortion per 100 feet of difference in altitude from datum plane*

Distance from focal center (yards)	Distortion (yards) for photo taken at—		
	10,000 feet	20,000 feet	30,000 feet
1,000	10	5	3
2,000	20	10	7
3,000	30	15	10
4,000	40	20	13
5,000	--------	25	17
6,000	--------	30	20
7,000	--------	35	23
8,000	--------	--------	27
9,000	--------	--------	30
10,000	--------	--------	33

88. Direction (fig. 34).—The effect of relief is to displace images radially from or toward the center of the photo. The effects are shown in figure 34. The points *a* and *b* are on higher ground, and the point *d* on lower ground, than the center of the photo. In the figure, *a*, *b*, and *d* represent the true locations of these points, whereas *a′*, *b′*, and *d′* represent the photo locations. The lines *a′d′* and *a′b′* are not true direction lines, whereas *ca′*, *cb′*, and *cd′* are true, and *b′d′* is approximately true. It follows that the direction of lines passing through points at or near the center of an average vertical photo are substantially true. However, lines joining points of different altitudes whose images lie in the outer field of the photo may show excessive errors when the relief is excessive. If the altitude from which the photo was taken is known, the error may be corrected by replotting the points to the same datum plane.

89. Scale.—*a.* From figure 31 it is evident that the scale of the photo can be expressed by the formula: RF (representative fraction) = focal length/height. Hence the scale of the photo and the area covered by the photo depend on the focal length and the height. For example, using the K-3 camera, which has a focal length of 12 inches (1 foot) and takes a picture 7 inches by 9 inches, if a picture be taken at a height of 20,000 feet, the scale becomes 1:20,000 and the area covered is (7 x 20,000) by (9 x 20,000) inches, or about 4,000 by 5,000 yards.

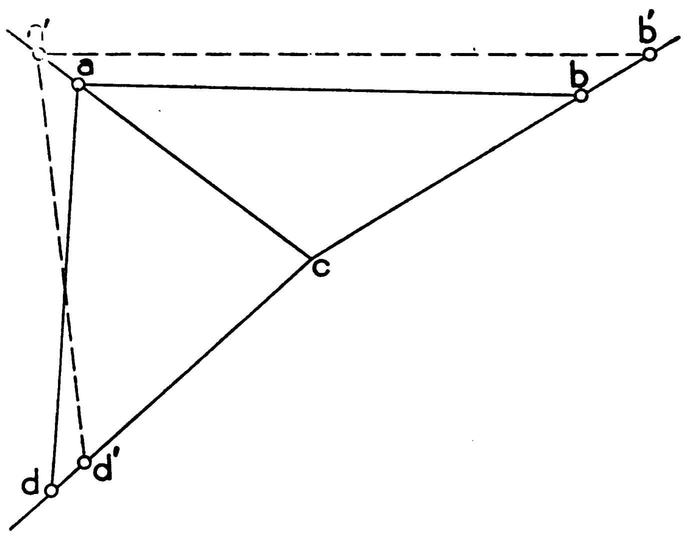


FIGURE 34.—Effect of relief displacements on direction and scale.

b. The scale of the photo as determined above is satisfactory when great accuracy is not essential. It is not strictly accurate for the following reasons:

(1) Because the altimeter may not have been set accurately at zero for the area photographed.

(2) Because of barometric variations which affected the altimeter.

(3) Because of shrinkage of negative and print.

c. (1) A more accurate method of determining the scale of a photo is to determine the relation between a photo distance in inches and the corresponding ground distance in inches. For example, if the photo distance between two points is 5.40 inches and the ground distance between the same two points is 3,100 yards, the scale is 5.40:(3,100 x 36), or 1:20,667.

(2) The points between which the distance is measured should be selected carefully. They should be well defined both on the photo or map and on the ground; they should be far apart and near the

average ground level so as not to bring in material error through distortion.

(3) Figure 34 shows the effect of relief distortion on the scale. The lengths of the radial lines *ca′*, *cb′*, and *cd′* are not accurate for the datum plane through *C*. Points *a* and *b* have been moved outward and point *d* inward by relief distortion; thus, for the datum plane through *C*, the lengths *ca′* and *cb′* are too great, and the length *cd′* is too small. To construct an accurate chart for the datum plane through *C*, *a′*, *b′*, and *c′* should be replotted (table II and fig. 34) at *a*, *b*, and *d*, respectively. Except in comparatively flat terrain, it is necessary to consider the possibility of relief distortion when selecting points.

(4) When determining the scale of a wide-coverage photo taken from a known altitude, it is desirable to select points at about the same altitude, or, if the altitudes differ materially, to replot one or both points to a selected datum plane. In case the points have the same altitude, the scale is determined for the datum plane of these points; for example, 1:20,300 at 1,600 (feet altitude). If the locations of the points have been replotted to a selected datum plane, the scale determined is the scale for the selected datum plane. Sometimes the average altitude of the ground covered by one portion of a photo differs materially from that of the ground shown on another portion. Consider a photo taken at an altitude of approximately 20,000 feet above the average ground level; assume that the average altitude of the higher portion of ground is 1,600 feet, and that the scale for this datum plane has been determined as 1:20,300. If the average altitude for the lower ground is 1,300 feet, the scale of this datum plane would be 1:20,600. Therefore if the scale for one datum plane has already been determined the scale for another datum plane, on the same photo, may be computed readily.

(5) A scale determined by using one point in the target area and the other in or near the position area often gives the best results because, while the scale obtained may not be the best for the photo as a whole, it is accurate for distances from the position area to the target area.

d. When the scale of a photo has been determined, photo measurements may be converted to true measurements (and true to photo) by the methods described below.

(1) *By use of K.*—When the photo is used as a firing chart, measurements may be made with the 1:20,000 scale and the true distances determined by the application of a *K* in the same manner as for *K*-transfers of fire. For example, the scale of a photo has been

determined as 1:21,180. Then *K* is 1180/20, or plus 59 yards per thousand. *K* is plus because the photo has a smaller scale than 1:20,000, the scale used for the measurements. If a scaled range is 4,500, the true range would be 4.5 x 59 + 4,500 = 4,765 yards.

(2) *By relation to any convenient scale.*—For example, the true distance between any two points identified on a photo has been determined as 1,500 *yards.* Using any convenient plotting scale, the distance between the same two points on the photo measures 1,800 *units.* The following relations then derive from the equation: True distance/photo measurement = 1500/1800:

True distance = photo measurement × .833 (1500/1800).
Photo measurement = true distance × 1.2 (1800/1500).

If the distance between two points on the photo is scaled as 2,100 units, the true distance between these points is 2,100 × .833 = 1,750 *yards.* If the true distance between two points on the ground is determined to be 1,200 yards, the photo distance between these two points is 1,200 × 1.2 = 1,440 *units.*

(3) *By use of slide rule.*—Using the method described in (2) above, the conversion of photo measurements to true distances (and the reverse) may be done quickly and accurately with a slide rule. The lower scale on the slide rule is labeled *true*, and the scale next above is labeled *photo* (fig. 35).

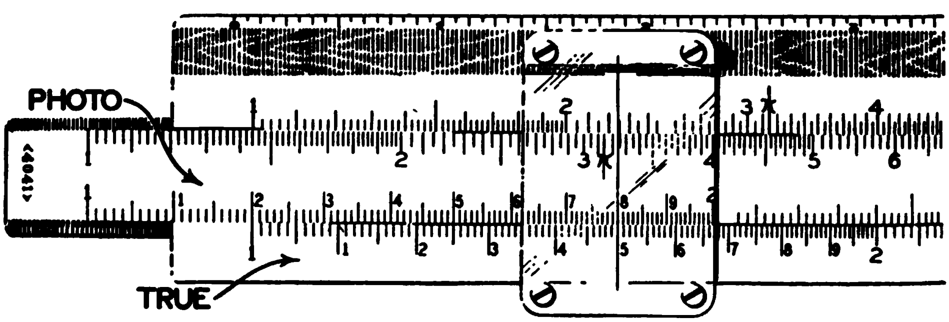


FIGURE 35.—Use of slide rule for conversion of photo measurements to true distances.

The scales are set in their proper relation according to the photo measurement and the corresponding true distance. Using the measurements given in the example in (2) above, the reading of 1,500 on the true scale is placed in line with the 1,800 of the photo scale. For example, to convert a photo measurement of 2,100 units to true distance, locate 2,100 on the photo scale and opposite it read on the true scale the true distance, 1,750 yards. Conversion from true distance to photo measurement is done similarly.

SECTION III

MOSAICS

	Paragraph
Types	90
Assembly of strip mosaic	91
Center-to-center method	92
Reconnaissance method	93

90. Types.—Mosaics are prepared by laying together a series of verticals.

a. An *uncontrolled mosaic* is compiled by matching the detail along the edges of the portions of the prints that are used.

b. A *controlled mosaic* is compiled by fitting the images of control points over their locations plotted on a control sheet; sometimes the prints must be rephotographed to bring them to the average scale or rectified if they are appreciably tilted.

c. A *strip mosaic* is laid by matching the centers and other points whose images appear on two or more overlapping photos, taken on a single flight line; a strip mosaic is thus partially controlled.

91. Assembly of strip mosaic (figs. 36 and 37).—A strip mosaic may be assembled from two or more overlapping vertical photos. It may be particularly useful as a substitute for the wide-angle photo. All vertical air photos have marginal information from which the center may be determined. The line joining the centers of successive photos is the course line along which the photos were taken.

92. Center-to-center method (fig. 36).—This method may be used when the photos overlap more than 50 percent.

a. Locate the centers of the first two photos. Select an object or feature near the center, on or near the course line, which can be identified on the adjacent overlapping photo. Label these selected points C–1 and C–2 on each photo.

b. Draw a straight line from C–1 to C–2 on each photo; prolong this line on photo No. 1 to the edge of the photo in the direction of flight.

c. To plot the control, orient photo No. 1 under the lower end of a piece of transparent paper of suitable size; mark accurately, with a fine point, the traced locations of C–1 and C–2; and draw the line from C–1 to C–2.

d. Replace photo No. 1 by photo No. 2, placing C–1 of the photo under C1 of the tracing with the lines from C–1 to C–2 on the photo and the tracing coinciding. If C–2 on the photo and the tracing coincide, its position is correct and the point on the tracing is circled and labeled C–2. Should the two points not coincide, a point halfway

between them is selected on the tracing, marked with a fine point, and labeled C-2.

e. Successive photos are treated in a similar manner.

f. Place the tracing of the traverse over the heavy mounting paper on which the photos are to be pasted. Prick through the several control points, label them, and join the several pairs with straight lines prolonged in the direction the plotting was done.

g. Pass a fine pin through C-1 of photo No. 1 and set it in C-1 on the mount. Rotate the photo until the line from C-1 to C-2 on the photo coincides with the plotted line on the mount. Fasten the photo with thumb tacks or "Scotch" tape in this position.

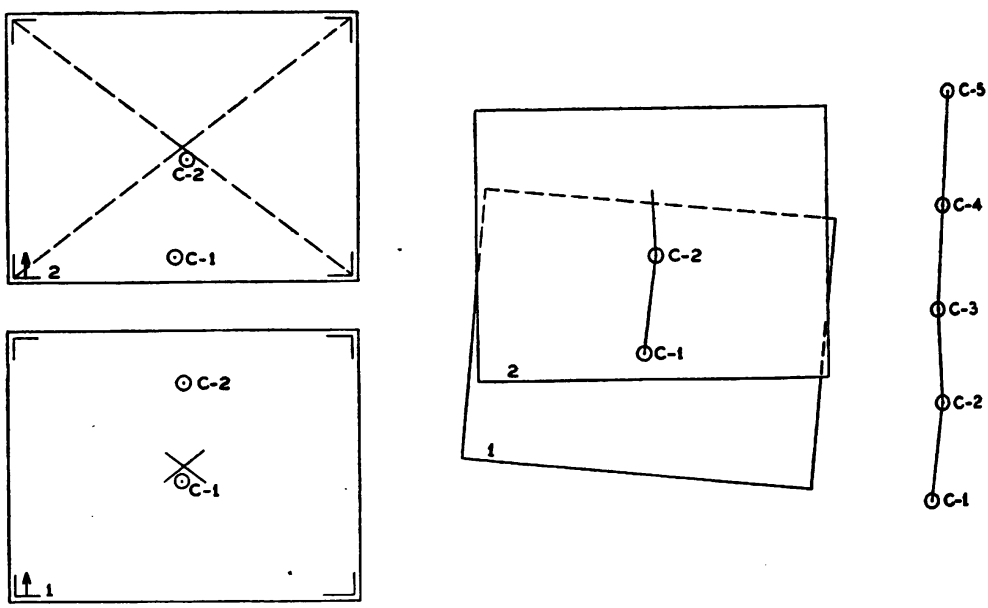


FIGURE 36.—Assembly of strip mosaic—center-to-center method.

h. In a similar manner, place photo No. 2 over C-2 and rotate until the lines from C-2 to C-3 coincide. Continue successively until all photos of the strip have been mounted. Cut across the middle of each overlap with a sharp knife and fasten down the loose edges. Rubber cement may be used to fasten photos to the mounting paper.

93. Reconnaissance method (fig. 37).—When the overlap is less than 50 percent, the center-to-center method cannot be used; the center of one photo will not appear on the succeeding photo. In this case, the reconnaissance method is appropriate. Except for the selection of points, the method is similar to the center-to-center method.

a. After the center of each photo has been marked, the photos are assembled in proper order. Two points, *A* and *B*, which appear on

both photos are selected, marked accurately with a fine pencil, and circled. These points must fall in the overlap, be close to the course line, and be as far apart as possible.

b. To plot the control, place photo No. 1 under the lower end of a piece of transparent paper and mark accurately, with a fine point, the traced locations of *A* and *B*; join the traced locations by a fine, straight line.

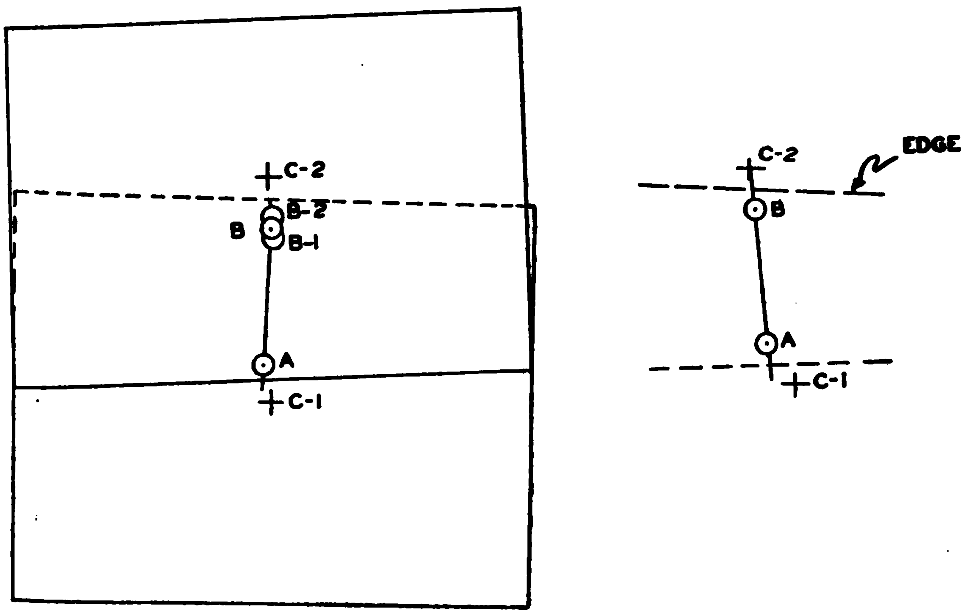


FIGURE 37.—Assembly of strip mosaic—reconnaissance method.

c. Replace photo No. 1 with photo No. 2 so that the point *A* on photo No. 2 falls under the point *A* traced from photo No. 1 and the lines from *A* to *B* coincide. If *B* on the tracing falls on *B* of photo No. 2, its position is correct and the point on the tracing is marked *B*. If the two positions of *B* do not coincide, mark a point halfway between its first traced position and its position on photo No. 2; circle; and mark this new point *B*.

d. Repeat this process, using different pairs of points for succeeding pairs of photos, until the points of all photos have been traced.

e. The method of mounting is similar to that described for the center-to-center method.

SECTION IV

RESTITUTION

	Paragraph
General	94
Intersection method	95
Ratio method	96
Radial-line method	97

94. General.—Restitution is the process of determining the map or chart locations of features appearing on air photos. The methods discussed refer to vertical air photos. When the photo and map are of the same scale, two points on the photo may be placed over the corresponding points on the map and the desired points pricked through to the map. When the scales are different, the problem is one of similar triangles, since corresponding angles on the photo and on the map are equal. The sides of the triangles are proportional in the ratio of map distances to photo distances. This principle may be applied in a number of ways, examples of which are discussed below.

95. Intersection method (fig. 38).—*a*. Two well-separated points whose chart locations are known are identified on the photo. The line joining them (*ab*) is taken as a base. The location of a point (*T*) is determined as follows: On the photo, draw lines from *T* to the ends of the base; on the chart, using the corresponding base *a′b′*, draw back rays making the same angles with the base as on the photo; the intersection of these rays is the chart location of the point.

b. When several points are to be transferred, the same procedure can be followed graphically. Fasten a sheet of tracing paper over the chart. Prick through the points *a′* and *b′* at the ends of the base. Draw the line *a′b′*, extended, if necessary. Then place the tracing paper over the photo, with *a′* over *a* and with the line *a′b′* passing through *b*. Draw rays from *a′* through each point to be transferred. Shift the tracing paper so that *b′* is over *b* and *b′a′* passes through *a*. Draw rays from *b′* through each point to be transferred. Now place the tracing paper again on the chart with *a′* and *b′* over their chart positions. Prick through to the chart the intersections of corresponding pairs of rays from *a′* and *b′*, thus transferring to the chart the positions of the points to be located.

c. For accurate results known points must be located accurately, and angles of intersection must be greater than 500 mils. Serious errors may result if the line selected as a base is in error because of distortion.

96. Ratio method.—*a.* Two well-separated points, *A* and *B*, whose map or chart locations are known, are identified on the photo. When there is a choice of points, select the pair so that the line joining

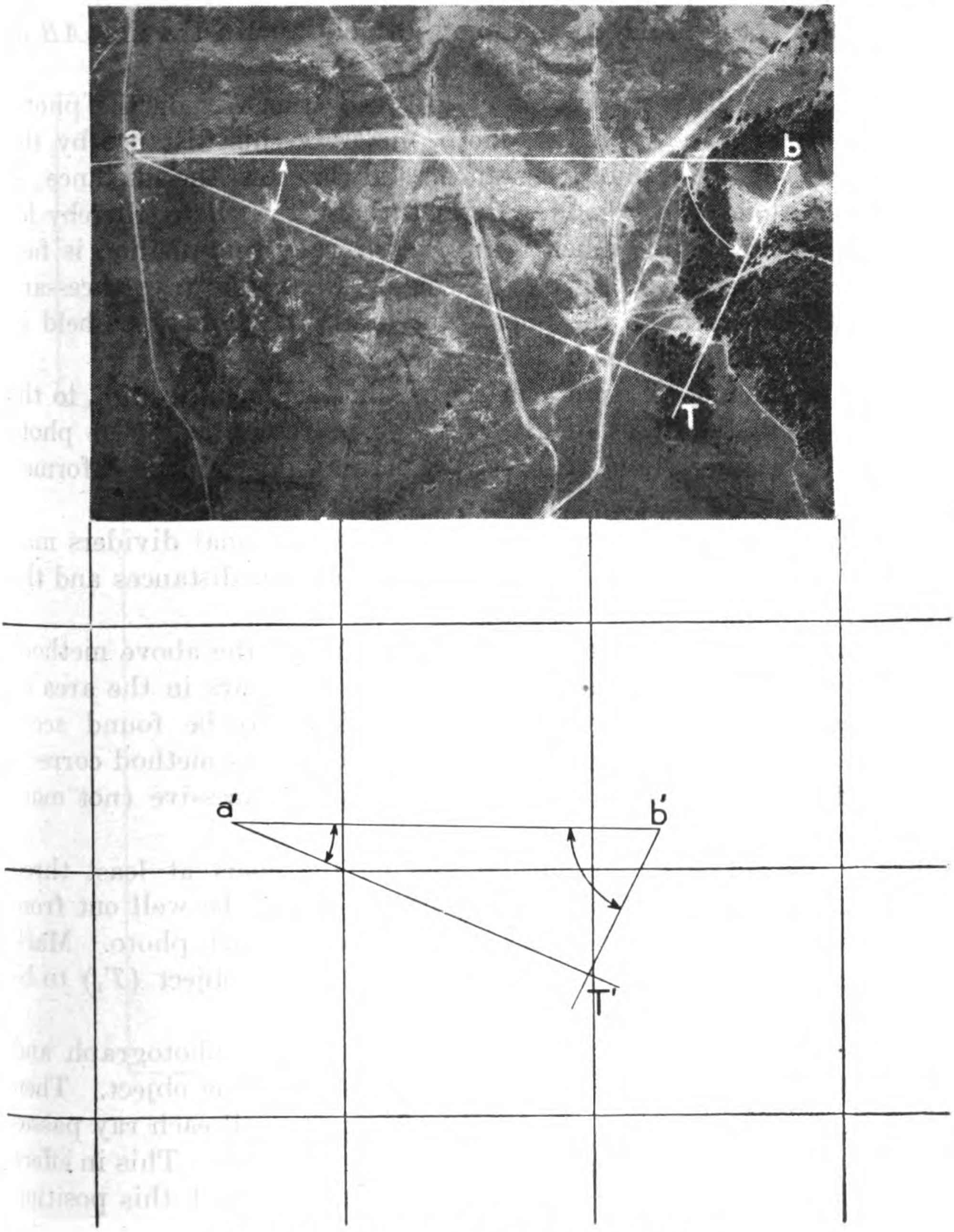


FIGURE 38.—Intersection method of restitution.

them passes through or near the center of the photo. Using any convenient scale, measure the map distance and the photo distance and determine the ratio: map distance/photo distance.

b. Draw a line through the two points on the photo and extend this line to the edges of the photo. Draw a line through the corresponding points on the map; extend this line beyond the edge of the photo.

c. Prick through point *A* on the photo and place over *A* on the map. Rotate until the line *AB* of the photo coincides with the line *AB* of the map. Fasten to map with thumb tacks.

d. (1) To restitute any point *P*, draw the line *AP* on the photo. Scale the distance *AP* on the photo, multiply this distance by the ratio—map distance/photo distance, and lay off the distance so determined along *AP* from *A*. Prick through the photo, thereby locating *P* on the map. When using a slide rule, this method is fast because of the fixed setting on the rule. It is not always necessary to draw the line *AP* on the photo; the straightedge may be held in place and the pin prick made along its edge.

(2) A slight modification consists of pin-pricking through, to the map, the photo locations of all points to be restituted. The photo may now be removed and all of the remaining operations performed on the map in a manner similar to that described above.

e. When applying a ratio graphically, proportional dividers may be used by setting one pair of points to read map distances and the other pair to read photo distances.

97. Radial-line method (fig. 39).—*a*. All of the above methods are approximate. If the object to be located appears in the area of overlap of two vertical pictures, its position may be found accurately on the chart by the radial-line method. This method corrects for relief and for tilt, provided the latter is not excessive (not more than 3°).

b. Identify on each photograph and on the chart at least three points (*A*, *B*, *C*, and *D*, fig. 39); the points should be well out from the center, and a different set may be selected for each photo. Mark the centers (P_1 and P_2) of the photos and also the object (T_1) to be located.

c. Place a sheet of tracing paper over the first photograph and draw rays from the center through the points and the object. Then place the tracing paper on the chart and adjust until each ray passes through the chart position of the corresponding point. This in effect resects the position of the center of the picture. Prick this position on to the chart; also prick a point on the ray from the center to the object to be located. Draw this ray on the chart.

d. Repeat the operation with the second photograph. The intersection of the two rays through the object to be located gives its chart position.

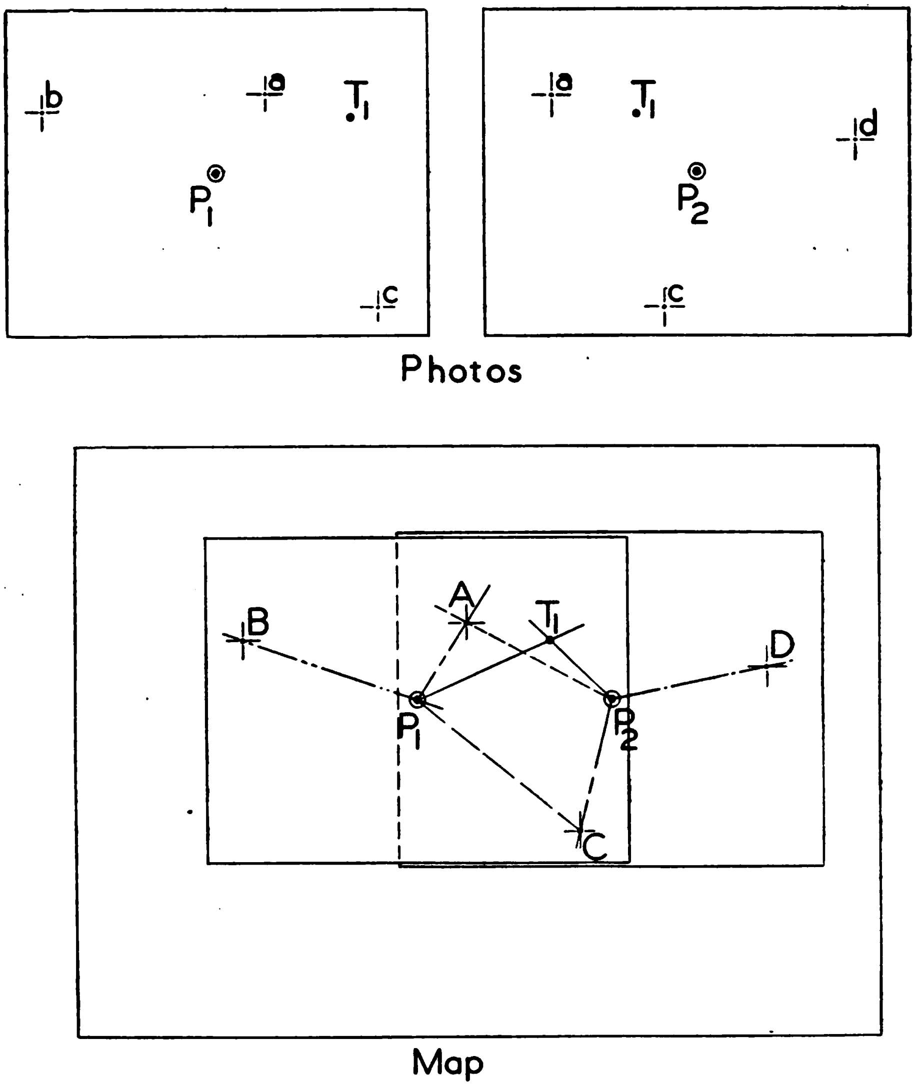


FIGURE 39.—Radial-line method of restitution.

CHAPTER 7

SURVEY PROCEDURE

	Paragraphs
SECTION I. General	98-99
II. Battle map	100-105
III. Wide-angle photo	106-114
IV. Grid sheet	115-118
V. Mosaics	119-122
VI. Location and laying of base pieces	123-126

SECTION I

GENERAL

	Paragraph
Firing charts	98
Necessary operations	99

98. Firing charts.—*a.* The basis of a firing chart may be any of the following:

Battle maps.
Wide-angle photos.
Grid sheets.
Mosaics.

b. Sections II to V, inclusive, describe the survey procedure appropriate to each of the above types of firing charts. Section VI describes the procedure to be used in locating and laying the base pieces.

99. Necessary operations.—In the construction of a firing chart, the information shown on the map or map substitute must be supplemented by additional information obtained by survey. To obtain this information, some or all of the operations listed below may be necessary:

a. Horizontal location of batteries and targets.
b. Determination of a direction.
c. Provision for transmission of direction to batteries.
d. Provision for vertical control.
e. Determination of the scale.
f. Extension of common control.
g. Location of observation posts.
h. Uniform declination of instruments.

Section II

BATTLE MAP

	Paragraph
Horizontal location of batteries and targets	100
Determination of a direction	101
Transmission of direction to batteries	102
Vertical control	103
Observation posts	104
Declination of instruments	105

100. Horizontal location of batteries and targets.—*a. Batteries.*—Depending upon the availability of identifiable points, the terrain, the accuracy desired, and the time available, batteries may be located as follows:

(1) By inspection, or by a traverse from some nearby point identifiable on the ground and the map.

(2) By an accurate traverse to all batteries of the battalion from some selected point of known location. The traverse usually is accomplished in two steps: first, a point in the vicinity of the battery is located; then the battery is located with respect to this point. The located point in the vicinity of the battery is marked by a stake or marker which is known as a *place mark.* A place mark is a stake or marker from which a battery determines its location or altitude, or both. The information furnished should be recorded on the place mark, preferably by means of a tag. The place mark should be near the battery for which it is intended; it is usually placed on the orienting line (fig. 40).

b. Targets.—Targets not shown on the map are usually plotted by their reported coordinates or by restitution from an air photo. Occasionally the location may be determined from observation posts or by adjustment of fire.

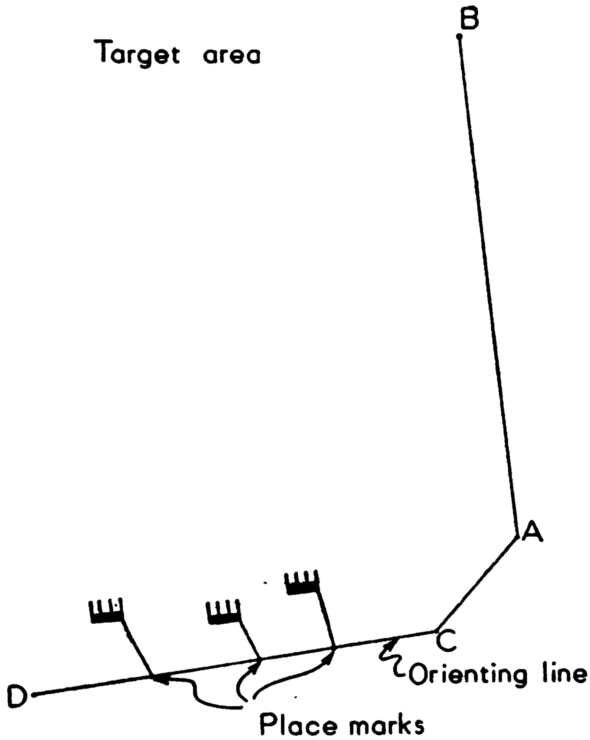
101. Determination of a direction.—*a. Two points.*—Direction usually is determined by two points which are well-defined on the map and the ground, and which are separated by as great a distance as practicable, never less than 1,000 yards. One of the points preferably should be in the target area. When points on the map are known to have been located with varying accuracy the more accurately located points are used to establish direction.

b. Astronomical methods.—The direction may be determined by accurate astronomical methods. The true azimuth is converted to *Y*-azimuth by using the variation indicated on the map.

c. Lining in.—In favorable terrain, direction may be determined by lining in the base piece and base point.

d. Aiming point.—Sometimes a distant aiming point whose map location is known may be visible from all base pieces of a battalion or larger unit. In this case, direction is determined by laying the guns with the proper deflection.

102. Transmission of direction to batteries.—*a. General.*—The established direction normally is transmitted to batteries by means of an orienting line. A traverse may be required to carry the established direction to the orienting line. The base angle, taken from the map or computed, is used to lay the guns.

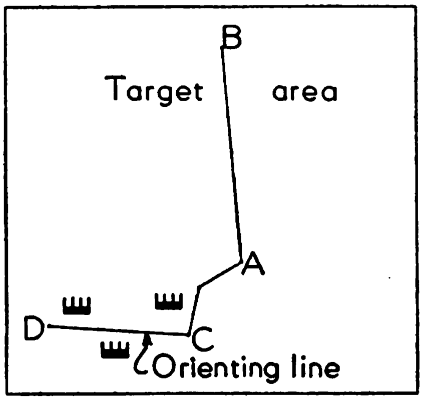


Line *AB* is used to establish direction and location of batteries. The traverse from *B* therefore includes measurement of both distance and angles. Place marks are located with respect to the line *AB;* for convenience they are placed on the orienting line *CD*.

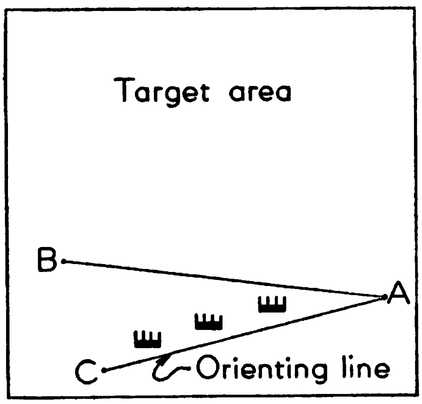
FIGURE 40.—Precise location of batteries.

b. Orienting line.—(1) An orienting line is a line of known direction, materialized on the ground, by which batteries are laid for direction. It is used to obtain uniformity and accuracy in laying. Normally one orienting line serves for all the batteries of a battalion. If practicable, one end should be marked by a distant, well-defined object which may be readily identified. The use of a distant object reduces the error in laying, because the error due to any inaccuracy in setting up the instrument on the orienting line is minimized by sighting on a distant point.

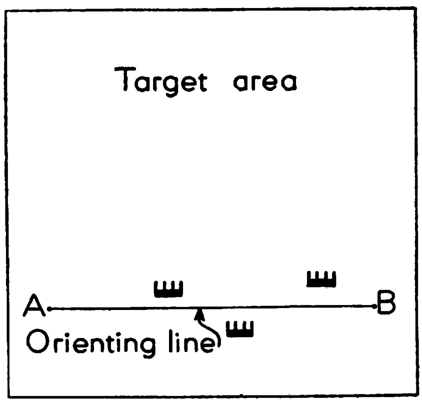
(2) The pieces of each battery should be visible from and within calling distance of one or more points on the orienting line. Stakes marking the line are so placed that at least one stake (or other object) on the line can be seen from any point on the line that is apt to be used. Stakes are carefully alined, firmly driven, marked for identification, and protected from disturbance.



① Line *AB* used to establish direction. Direction of orienting line determined by a traverse from *A*.



② Line *AB* used to establish direction. Direction of orienting line determined by measurement of angle *BAC*.



③ Line *AB* used to establish direction and also as the orienting line.

FIGURE 41.—Direction of orienting line.

(3) The direction of the orienting line may be determined by a traverse from some other line of known direction (fig. 41①) by turning off an angle from a line of known direction (fig. 41②), or by being so placed as to pass through two well-separated points identifiable both on the ground and on the map (fig. 41③). A direction established with both points outside the target area should be checked as soon as practicable against some point within the target area.

103. Vertical control.—*a. Contoured battle map.*—(1) Depending on the terrain and the accuracy desired, the altitudes of batteries may be determined by interpolation between contours, or by traverse from the place marks located by the battalion. The altitude used by the battalion is determined from a bench mark, if one is available, or from the contours.

(2) The altitudes of targets habitually are determined from the contours.

b. Uncontoured battle map.—Altitudes of targets and points in the position area are computed from instrument readings taken from a point of known altitude, or from a point to which is assigned an arbitrary altitude. In order that meteorological data may be used with accuracy, the arbitrary altitude should not vary greatly from the actual altitude. The range used in the computation is taken from the map.

104. Observation posts.—For high-burst and center-of-impact adjustments, observation posts must be selected and their locations determined. The same principles apply with respect to methods of accuracy of locating observation posts that apply to locating base ends for a long-base intersection (par. 73). If no reference point is indentifiable both on the ground and on the map, a reference point must be located on the map by accurate survey. When the observation posts are mutually visible they may be used as reference points; for such use they must be accurately located. If night registrations are required, the instruments must be oriented during daylight, or their lines of sighting must be staked out so that they may be oriented at night.

105. Declination of instruments.—When practicable, a declinating station is established for the purpose of determining the declination of instruments with respect to *Y*-north of the battle map. The point chosen for the station should be free from local magnetic attraction and should permit a view of one distant, well-defined object with a direction of known *Y*-azimuth; as a check, additional objects are desirable. In the absence of an established declinating station, an instrument may be declinated for any particular locality by setting up on any line of known azimuth.

Section III

WIDE-ANGLE PHOTO

	Paragraph
Horizontal location of batteries and targets	106
Determination of a direction	107
Transmission of direction to batteries	108
Vertical control	109
Scale	110
Construction of firing chart to reduce relief distortion	111
Common control	112
Observation posts	113
Declination of instruments	114

106. Horizontal location of batteries and targets.—*a. General.*—In average terrain, the relative horizontal locations of points on the wide-angle photo are satisfactory for the preparation of fire. A battery plotted in its photo location can ordinarily fire with satisfactory accuracy on targets located with reference to the photo. If the terrain is rugged, registration, the reduction of horizontal errors by survey, or the replotting of critical points to a selected datum plane is usually required for effective fire.

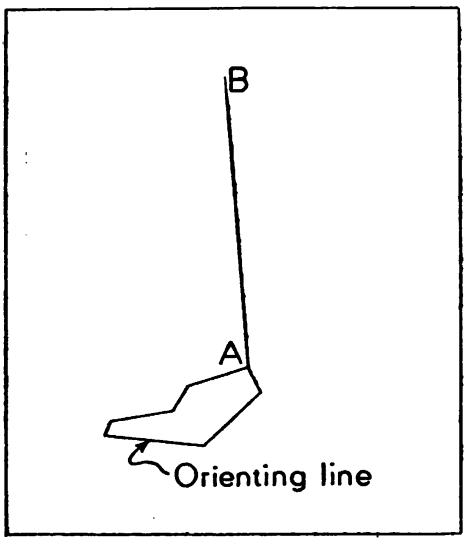
b. Location of batteries.—When time is limited, batteries are usually located by inspection or by a traverse from some nearby identifiable point. When time permits and greater precision is desired, batteries are located by accurate traverse from some specific point; preferably a point which has been tied to the target area. In such case, the traverse used to bring direction to the batteries may serve also to determine their location (fig. 40). This method of locating batteries is advantageous when several battalions are to be accurately tied together. Normally, however, when time is limited, batteries are located in their actual photo positions. In rugged terrain, the photo positions should be replotted to correct for relief distortion.

c. Location of targets.—(1) In flat or gently rolling terrain, the photo location usually may be taken without correction. In rugged terrain, corrections of different parts of the target area may be necessary for accurate fire. These corrections are accomplished by registrations, by locating control points in the target area, and by replotting to correct for relief distortion. A basic correction in range may be made by using a point in the target area for the determination of the scale.

(2) When the location of the batteries has been determined with respect to a point in the target area (fig. 40), that part of the target area normally needs no further correction. In rugged terrain, other parts of the target area may also need correction.

107. Determination of a direction.—*a. Two points.*—(1) In general, direction is established in the same manner as with a map. Possible distortion, however, makes the use of a long line with one point in the target area (fig. 41①) of greater importance. When practicable, direction should be established in this manner. In flat terrain, any two well-separated points, well defined on the photo and the ground, are satisfactory. As the terrain becomes more uneven, greater care must be taken to avoid error from relief distortion (par. 111).

(2) Frequently it is desirable for several battalions to use the same basic line for direction. Corrections determined by one battalion



Line *AB* used to establish direction. Direction of orienting line is determined by traverse which starts and closes at *A*.

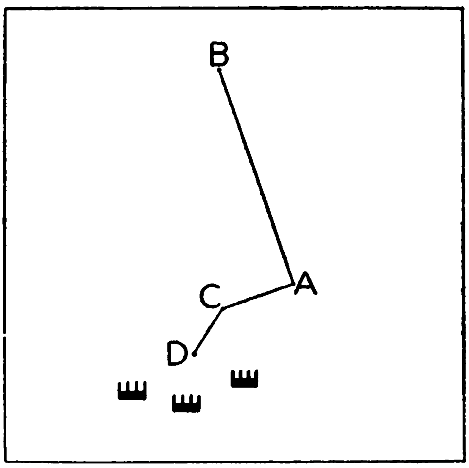
FIGURE 42.—Closed traverse.

through survey or firing may then be more readily utilized by other battalions.

b. Astronomical methods.—With air photos, astronomical readings are utilized in a different manner than with a map. The azimuth between two points on the photo must first be determined by astronomical readings in order to orient the photo. When this has been accomplished, battalions or batteries determine a similar azimuth for an orienting line, preferably by a reading on Polaris, and lay their batteries accordingly. The angle between the base line and the line of known azimuth which orients the photo is the basis for the laying. Laying by astronomical methods, when accurately performed, establishes a uniform direction for all battalions using the photo. When

simultaneous readings are made, the true azimuth need not be determined; the azimuth assigned the designated line on the photo is the clockwise angle measured from the sun or Polaris at the moment the readings are taken.

108. Transmission of direction to batteries.—With an air photo, direction is transmitted to batteries in the same manner as with a map. Since, when practicable, a line with one end in the target area is used to establish direction, a traverse to the battalion position area more often is used in carrying the established direction to batteries. This traverse may be used to establish an orienting line as in figure 41①, or a closed traverse (fig. 42) may be employed to assure accuracy. When all batteries can be seen from one point, a traverse to this point may suffice (fig. 43).



Line *AB* used to establish direction. Direction is carried by traverse to point *D*, where all batteries may be seen. The line *DC* actually is the orienting line, which may be prolonged through the position area if necessary.

FIGURE 43.—Direction given all batteries from one point.

109. Vertical control.—*a. Control points.*—Since an air photo normally is not contoured, the vertical relation of batteries and targets must be determined by survey. The altitudes of control points, usually terrain features identifiable on the photo, are computed from site readings taken from a point of known or assigned altitude as described in paragraph 103*b*. The range used in the computation is taken from the photo. If the control point cannot be identified by inspection, it must be located by survey. The number of control points needed for vertical control depends primarily on the terrain. In flat terrain the points may be widely separated; one point may suffice for the entire target area. In rough broken terrain many points may be needed to provide satisfactory vertical control.

b. Stereoscopic examination.—Estimation of the difference in altitude between the target and control point may be made with greater accuracy by the use of stereoscopic methods, which give a clearer picture of the relief (FM 21-25 and FM 30-21).

c. Medium-scale map.—When a contoured medium-scale map is available, the altitudes of batteries and targets may be taken from the map. Altitudes of critical points should be checked, when possible, by computations from instrument readings. A map of the type of the 1:62,500 United States Geological Survey map ordinarily provides vertical control comparable in accuracy with that practicable by survey.

110. Scale.—*a. General.*—Wide-angle photos are most satisfactory for field artillery use when printed at a scale as close to 1:20,000 as practicable. Corrections for variation from this scale must be determined by survey.

b. Determination.—(1) Scale is determined by comparing photo distance to ground distance as taped or computed (par. 89*c*). In flat terrain an accurate measurement between any two points, well defined on the photo and on the ground and separated by about 2,000 yards, is satisfactory. In general, the greater the distance between the points the more accurate is the scale. When the terrain is rugged, points must be selected which do not introduce a noticeable error from relief distortion, or the points must be replotted to a selected datum plane.

(2) A line with one end in the target area and the other within our lines usually produces a satisfactory scale, provided the line is sufficiently long. A scale determined in this manner actually serves as a range correction for locations in the target area. Additional information on relief distortion and the determination of the scale is found in paragraphs 87, 88, 89, and 111.

c. By whom determined.—The scale of the photo often need be determined by one survey section only. All battalions are then informed of the scale to be used. As indicated in paragraph 89*d*, the variation from 1:20,000 may be applied as a *K*.

111. Construction of firing chart to reduce relief distortion.—*a.* For accuracy in rough terrain, the firing chart is constructed to a selected datum plane. All critical points should be replotted to this plane, including points used to establish direction and scale, batteries and, when necessary, targets.

b. The datum plane upon which the firing chart should be constructed usually is the average ground level of the target area. In such case, the locations of the bulk of the targets normally need

not be replotted. In some situations, area or locality corrections may be determined for targets within a particular area.

c. While corrections for targets usually are not necessary except in rough terrain, direction and scale can be corrected so readily that it is advisable to do so in moderately rolling terrain. If no corrections by replotting are to be applied, three rough rules should be kept in mind—

(1) For direction, use well-separated points of about the same altitude, or well-separated points on a radial line from the center of the photo.

(2) For scale, use well-separated points of about the same altitude, preferably at the average ground level.

(3) For both scale and direction, use a point in the target area *when such point may be accurately identified on the ground and on the photo.*

112. Common control.—*a.* When common control and a wide-angle photo are both available, the fire-control grid system normally should not be placed on the photo. Tilt, relief distortion, and difference of scale make accurate gridding impracticable. Therefore a grid sheet should be used for missions designated by fire-control coordinates and the photo for other missions.

b. When the accurate locations of two or more points in the target area, identifiable on the photo, have been determined, these points may be plotted on the grid sheet and all targets transferred thereto by restitution. Data may now be prepared from the grid sheet and the photo not used as a firing chart. In some situations an accurate ground survey may be initiated or completed before the photo is available; in this case, the photo may be used only for restitution. If, however, suitable control points in the target area cannot be identified on the photo and on the ground, the photo must be used as the firing chart except for those targets designated by fire-control coordinates.

c. In general, when the wide-angle photo is used as a firing chart, the fire-control grid is of little or no value because targets habitually are designated by methods having no connection with this grid. But when targets are designated by fire-control coordinates, a grid sheet should be used.

113. Observation posts.—Observation posts for high-burst or center-of-impact adjustments are established in the same manner as described for a battle map (par. 104). When practicable, the reference point should be in the target area and near the point of adjustment. In such case the photo location or, in rugged terrain,

the replotted location of the reference point should be used. If no suitable reference point in the target area can be identified on the photo, one should be located by survey based, preferably, on the two points used to establish direction. In either case, since the reference point is near the point of adjustment, the observation posts may be located by inspection or short traverse.

114. Declination of instruments.—The declinating station, described in paragraph 105, is also desirable when using the wide-angle photo. When observations can be made on Polaris, true azimuth is used. When there are no other means, an approximate azimuth is adopted.

Section IV

GRID SHEET

	Paragraph
General	115
Procedure	116
Advantages and disadvantages	117
Common control	118

115. General.—For the preparation of unobserved fires, except on targets located by sound, flash, or radio intercept, the grid sheet must be supplemented by air photos of the target area. The survey must include accurate control of these photos. When counterbattery based on data secured from the observation battalion is to be fired, a grid sheet should be maintained for these missions. At times, battalions may find it necessary to maintain the grid sheet for counterbattery missions and the wide-angle photo as the firing chart for other unobserved fires.

116. Procedure.—As compared to the battle map or wide-angle photo, the principal difference in procedure is that the location of all points which are to be used must be determined and the points plotted. Batteries and control points in the target area must be located by survey; detail in the target area must be plotted by restitution. The locating of control points in the target area is the most difficult part of the survey with a grid sheet. In order to restitute targets, suitable points identifiable on the ground and on the photo must be available. These must be located by accurate survey. At least two such points, far enough apart to secure accurate control of the photo, are required. When these points have been located on the chart, targets are plotted by restitution. Vertical control is established in the manner described in paragraph 103*b* for the uncontoured battle map, except that the location of all points used for altitude control must be determined by survey or restitution.

117. Advantages and disadvantages.—If the survey is performed with accuracy and suitable control points are available in the target area, the grid-sheet survey produces an accurate firing chart. However, difficulty may be encountered in the accurate identification of control points in the target area. Suitable points frequently do not exist. Another disadvantage of the grid sheet is that the time necessary for survey often is prohibitive in moving situations. When common control is available, the use of the prescribed fire-control grid system permits the accurate massing of artillery fire on targets of known coordinates.

118. Common control.—*a. General.*—The use of the fire-control grid system to coordinate artillery fire usually involves a ground survey to extend common control to subordinate units; batteries and targets must always be located with relation to the prescribed grid system.

b. Basic information.—The echelon ordering common control is responsible that subordinate units are furnished with the necessary basic information as to coordinates, azimuths, and altitude. This is accomplished by a survey which extends the control within reach of subordinate units, or by the designation of suitable geodetic points. When control is local, an arbitrary grid system and an arbitrary altitude (which should not differ greatly from the actual altitude) are chosen; control points based on the arbitrary data are established for use by subordinate units.

c. Subordinate units.—Subordinate units habitually execute their own surveys without waiting for control data. This survey includes the determination of the relative positions of batteries and points in the target area. When common control is anticipated, the battalion determines accurate relative locations and altitudes by survey and is prepared to adopt the prescribed control when the necessary information is made available. The higher echelon often can facilitate the work of subordinate units by informing them in advance of the manner in which control will be furnished. For example, the division artillery survey section may indicate to battalions that the coordinates and altitude of a designated point and the *Y*-azimuth to another designated point will be furnished later.

d. Methods and precision.—(1) The survey is extended by the use of the survey operations described in chapter 5. Traverse (carrying direction, distance, and altitude) is the usual method employed. In open terrain, points may be located or distances may be determined by short-base or long-base methods. In general, the survey in extending control must be performed with great precision. The degree of

allowable error depends upon the final effect. A slight error in direction when carried forward a considerable distance may produce an excessive error in the preparation of fire. On the other hand, if the survey has been precise up to the location of the place marks, approximate methods will suffice for the location of the battery with reference to the place mark. However, direction upon which fire is based must always be precise. The direction of the orienting line must be as precise as possible; the laying of the batteries on the base line must be executed with great accuracy. While errors of a few yards in the location of the guns has little effect on the accuracy of fire, errors in direction, even though relatively small, have a pronounced effect on the accuracy.

(2) The survey for extending control often must be performed at night. When practicable, reconnaissance of routes and the locating of critical points should be accomplished before dark. For night work, special equipment is desirable (ch. 8).

Section V

MOSAICS

	Paragraph
General	119
Controlled mosaics	120
Uncontrolled mosaics	121
Strip mosaics	122

119. General.—The survey procedure, when using a mosaic as the firing chart, depends primarily on the accuracy of the mosaic. In general, controlled mosaics are accurate; uncontrolled mosaics may or may not be accurate, depending on the terrain, the skill with which they are assembled, the number and type of photos used, and the accuracy and scale of the individual photos.

120. Controlled mosaics.—The controlled mosaic, when reproduced without loss of detail, combines the grid of a battle map with the detail shown on a wide-angle photo; its horizontal accuracy is almost as good, because the outer portions of the individual photos are seldom used, and there is little distortion remaining unless the terrain is very rugged. The procedure is therefore the same as for an uncontoured battle map, except that restitution from other photos is more easily accomplished.

121. Uncontrolled mosaics.—Ordinarily the errors in an uncontrolled mosaic are not predictable and can be determined only by firing or accurate survey. The errors habitually vary in different parts of the mosaic. The accuracy usually is satisfactory for transfers

but may or may not be satisfactory for map data corrected. To check the accuracy by survey, points in different parts of the target area, identifiable on the mosaic and on the ground, must be accurately located. Corrections may thereby be provided in direction and range for the different parts of the mosaic. When these corrections have been determined, unobserved fires without registration are practicable. Usually, however, unless the mosaic has been very accurately assembled or consists of only two overlapping photos, unobserved fires should be limited to those based on registrations. The development of accurate methods of assembly may improve the accuracy of uncontrolled mosaics to the point where they will be suitable as firing charts. At present, the wide-angle photo is preferable because the amount and direction of its relief distortion can be determined; this normally cannot be determined for the uncontrolled mosaic.

122. Strip mosaics.—*a. General.*—Strip mosaics must be assembled accurately in order to be satisfactory as a basis for a firing chart. Each photo must be accurately oriented in the process of assembly, or effective transfers of fire cannot be made.

b. Wide-angle photo strip.—Survey procedure for the wide-angle photo is generally applicable to the wide-angle photo strip. Determination of scale and direction preferably should be based on a point in the target area and one in the position area in order to minimize possible errors in assembling the strip.

SECTION VI

LOCATION AND LAYING OF BASE PIECES

	Paragraph
Location of base piece	123
Determination of base angle	124
Error of base angles	125
Preparation for night occupation of position	126

123. Location of base pieces.—*a. By inspection or short traverse.*—Often the base piece is at or so close to a terrain feature or object appearing on the map or photo that its position may be plotted by inspection. When the base piece is within a few hundred yards of an identifiable point, it may be located by a short traverse, direction being taken from another identifiable point. In terrain devoid of detail, difficulty may be encountered in locating batteries by these methods. The procedure is used solely to gain time. Therefore in unfavorable terrain, when no time is gained, locating by place marks as described in paragraph 100*a*(2) is preferable. In average terrain, location by inspection or short traverse may be accomplished readily. The loca-

tions should be determined as accurately as practicable. An error which does not exceed about 10 yards ordinarily is satisfactory. When using a map, air photos are of great assistance; smaller verticals showing greater terrain details assist in determining locations on the wide-angle photo.

b. From place marks.—Place marks usually are established on the orienting line; base pieces are located by traverses from these marks, the initial direction for the traverses being taken from the orienting line. In some situations, a place mark not on the orienting line may be used; in this case the place mark is used only for locating the pieces,

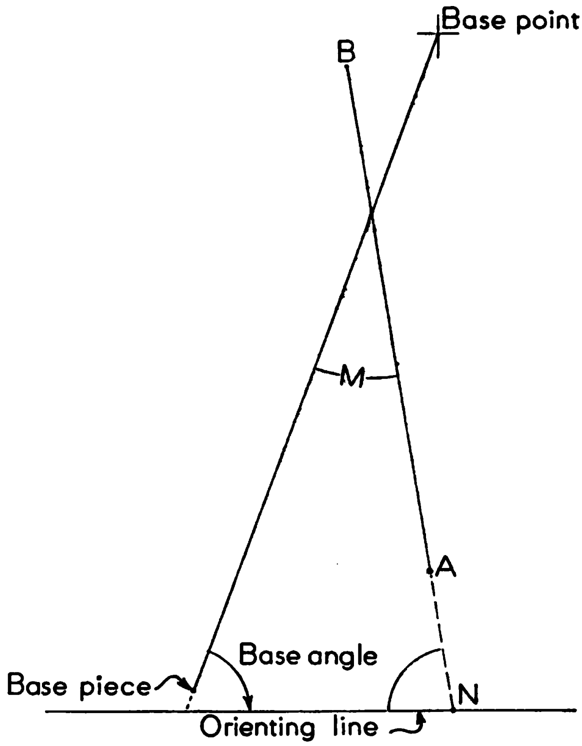


FIGURE 44.—Computation of base angle.

while direction for laying them is transmitted by an independent directional traverse from the line which establishes basic direction. When the place mark is used only for locating the pieces, a known direction is necessary at the place mark in order to initiate the traverse from that point.

124. Determination of base angle.—*a.* The base angle is the clockwise angle between the base line and the orienting line. It may be determined either by plotting the orienting line, base piece, and base point on the firing chart, or by computation based on the angle between the base line and the line used to establish direction.

b. When the direction of the orienting line is determined by a directional traverse, the orienting line may be plotted anywhere on the firing chart, provided its direction is correct.

c. The base angle may be determined without plotting the orienting line by using the relation between angles measured and those taken from the chart. For example (fig. 44), the line *AB* is the line used to establish direction. A directional traverse has been run from *A* to the orienting line. The base piece has been located by inspection. The angle *M* is measured on the chart. The angle *N* is known because the direction of the orienting line is determined by traverse from

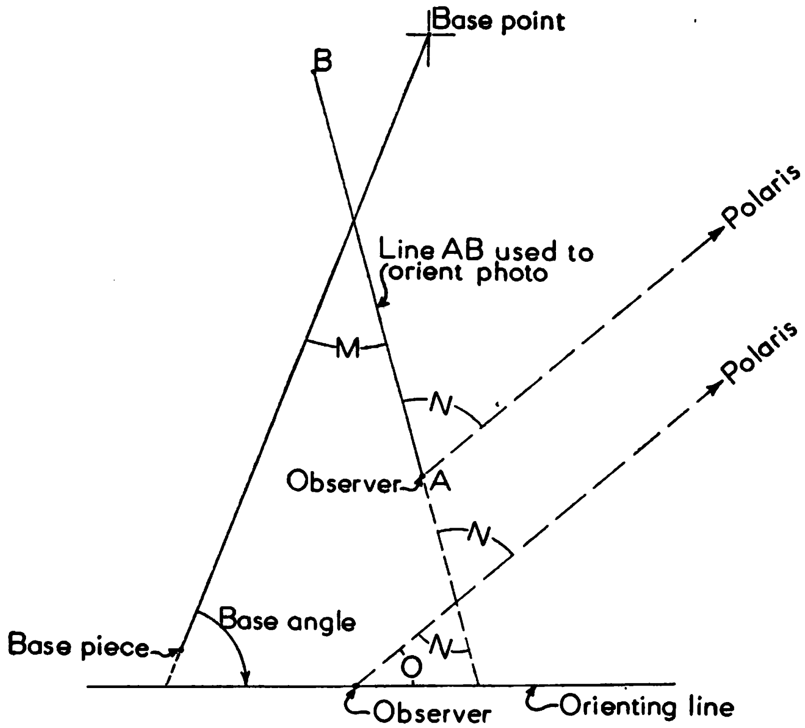


FIGURE 45.—Computation of base angle when direction is established by astronomical methods.

A. The base angle is $3200-(M+N)$. The same procedure is applicable when direction is determined by astronomical methods. In figure 45, the angle *N* is known because the azimuth of the line *AB* with reference to Polaris is furnished. The angle *O* is known because the observer sets up the instrument on the orienting line and, after the observation on Polaris, reads the angle to the orienting line. The base angle is $O+N-M$.

125. Error of base angles.—The error in the determination of the base angles depends upon the accuracy of the survey, the accuracy with which angles are plotted and measured on the firing chart

or supplementary large-scale chart, and, if photo locations are accepted for the batteries, the accuracy of these locations with respect to the target area and the points used to establish direction. Precision in survey reduces the survey error; precise workmanship in plotting and measuring angles reduces the error in these operations; and replotting to a common datum plane removes most of the error caused by faulty locations. When speed is required, an error in the base angle up to about 10 mils in direction may be accepted initially. This error should be reduced as quickly as practicable by more precise work or by registration. The expected error in laying the batteries on the base line must also be considered.

126. Preparation for night occupation of position.—*a.* If the position is to be occupied during darkness, the position of each piece and of the executive's instrument is determined and marked by stakes during the hours of daylight prior to occupation. Data are determined to give the battery its initial laying; means to lay the battery promptly on its arrival must be provided. The battery may be laid by the aiming circle; in this case, the instrument should be set up and laid for direction during daylight, the 0–3200 line materialized on the ground, and a guard placed over the instrument until the battery is laid. An alternate method is the following: An aiming circle is set up at the position of each piece in turn; it is laid for direction as if it were a piece; then, by turning the upper motion of the instrument to any convenient deflection setting as (3000), two aiming stakes for that piece are accurately alined on the line of sighting; the deflection thus determined (3000) is recorded and is used later to lay the piece. After the arrival of the pieces the alinement of the aiming stakes must be verified; if the stakes are out of alinement because of a displacement of the gun sight, a displacement correction is applied as described in paragraph 30, FM 6-40.

b. If the base angle (or data necessary to lay the base piece) will not be known until after dark, an arbitrary base angle should be assumed and the procedure prescribed in *a* above followed. The pieces having been laid on an arbitrary base angle, the executive shifts the pieces right (left) by the difference between the arbitrary base angle and the correct (determined) base angle. Example: The battery is laid on an arbitrary base angle of 1900. The determined base angle is 2108. The executive commands: ***LEFT 208, RECORD BASE DEFLECTION.*** (If base deflection had been recorded on the arbitrary direction, the command is: ***BASE DEFLECTION LEFT 208, RECORD NEW BASE DEFLECTION.***)

c. If registrations or adjustments are to be made during darkness, the executive's instrument and any other instruments required for observation are laid during daylight by the best means available. A means of establishing the line of sighting to each base or check point is materialized on the ground by stakes. When possible, these instruments should be oriented by sighting on an accurately located point in the target area.

CHAPTER 8

NIGHT SURVEY

	Paragraphs
SECTION I. General	127-129
II. Special equipment	130-133
III. Special methods	134-138

SECTION I

GENERAL

	Paragraph
Requirements for night survey	127
Characteristics of night survey	128
Training of survey personnel	129

127. Requirements for night survey.—Night survey is more difficult than survey during hours of daylight and is slower. Every effort must be made to limit the amount of night survey to be performed by taking full advantage of available daylight hours. Only when the situation precludes daylight survey will night survey be chosen deliberately.

128. Characteristics of night survey.—*a. General.*—Due to the handicaps imposed by darkness, night survey is generally limited to the topographic location of points that can be occupied by survey personnel. Because of the difficulty of making identifications at night, routes of survey will largely be along established roads and trails. Cross country operations will be limited to those which cannot be reasonably avoided.

b. Special equipment for night survey.—Reticles and scales of instruments should be artificially lighted. Personnel should be equipped with suitable flashlights. Rods modified or designed for sighting targets should be used.

c. Advantages of night survey.—Darkness provides protection against enemy terrestrial and air observers.

d. Disadvantages of night survey.—(1) Identification of terrain features is difficult.

(2) Movements of personnel are hampered.

(3) Operation of instruments is more difficult, and taping is slower and more liable to error.

(4) Rapid methods of survey, such as intersection, resection, stadia, and short or long base methods are rarely possible.

(5) Survey operations on traveled roads are dangerous and sometimes impossible due to vehicular traffic.

(6) The necessity for the use of lights may result in exposure to enemy observation.

(7) Materialization of direction on the terrain is difficult and subject to error unless extreme care is taken.

(8) In general, any particular survey operation takes about three times as long in darkness as it would take in daylight.

(9) Night survey is appreciably less accurate than day survey.

129. Training of survey personnel.—*a.* Field artillery survey personnel should be trained in night survey. Night work should not be attempted until personnel is qualified in daytime operation. Repetition at night of surveys conducted in daytime will illustrate the difficulties to be encountered, the variations in methods made necessary by darkness, and the relative accuracy to be obtained.

b. Night survey should be carefully supervised to insure that exposure incident to use of lights is reduced to a minimum, particularly in the vicinity of establishments and battery positions.

Section II

SPECIAL EQUIPMENT

	Paragraph
Instrument lights	130
Sighting targets	131
Station markers	132
Equipment for survey personnel	133

130. Instrument lights.—Lighting equipment is provided for aiming circles, illuminating the reticle, and including a finger light for illuminating the scales and bubbles. Some transits are equipped with built-in lighting equipment which illuminates the reticle and verniers. When the transit is not so equipped, the operator must use a flashlight, preferably one whose lens has been hooded to reduce the light aperture. In any case, a flashlight must be used in setting up the transit. Battery commander's telescopes are equipped with lighting equipment similar to that on the aiming circle.

131. Sighting targets.—Any source of light that is visible through the telescope of an instrument and has sufficient definition to permit accuracy in laying is satisfactory as a sighting target. For short shots, the range pole or even the string of the plumb-bob may be illuminated by a flashlight. For longer shots, the flashlight itself may

be used as a target, care being taken to hold it directly over the station mark being sighted on. In light mist or fog for comparatively long shots on surveys not requiring too great accuracy, the headlight or taillight of a car may be used.

A rod suitable for accurate work with the transit can be improvised as follows: A metal tube of about the dimensions of an aiming post is used. Longitudinal slits about 3 inches long are cut in the side of the pipe, one at the center and one near each end. Flashlight bulbs are mounted in the pipe, above and below each slit. Current is furnished by BA-30 cells taped to the pipe.

132. Station markers.—*a.* Darkness increases the difficulty of identifying stations to survey personnel. The most reliable method is to employ a guide who can lead the party to the station. When stations are sited near a road, conspicuous signs visible from the road may be used to indicate the location.

b. The position of the station should be indicated by some form of marker that can be readily identified at night. Either the station itself should be indicated with a white cloth or similar signal, or, if the marker itself is driven deep in the ground to protect it from being displaced, a witness stake, prominently marked, should be placed within a yard of the station to identify it. In the latter case survey personnel should be cautioned to avoid confusing the witness stake and the station.

c. Where direction is to be established by a reference marker, visible from the station when illuminated, identification of the reference marker will be facilitated by placing a marked stake about 10 yards from the station in the direction of the reference marker.

d. A station which is likely to be used again should have attached to it a tag giving such of the following information as is pertinent:

(1) Survey organization which established the station.

(2) Number or designation of the station.

(3) X, Y, and Z coordinates of the station.

(4) Designation of a reference marker with the azimuth and approximate distance thereto.

133. Equipment for survey personnel.—Each member of the survey party should be equipped with a flashlight. A lightproof shelter should be available when plotting and computing are to be done. The body of a truck with curtains down is satisfactory.

Section III

SPECIAL METHODS

	Paragraph
General	134
Orientation	135
Traverses	136
Intersections and resections	137
Plotting and computing	138

134. General.—*a.* Every effort should be made to initiate survey before dark, and at least to reconnoiter during daylight the terrain to be traversed in order to select routes and plan the survey operation.

b. Routes of night survey should, as far as posssible, be chosen along roads or open trails or across open terrain. Routes over difficult ground or through woods should be avoided. If daylight reconnaissance has not been made, a night reconnaissance of the route should be made prior to survey.

c. Surveys performed at night should habitually be checked during daylight hours.

d. Due to the slowness of night survey, initiation of survey should not await the survey of a higher echelon. By prearrangement, the survey party of the higher echelon can run its survey to a designated point in the area of the lower echelon. In this manner, the lower echelon can initially employ an assumed direction, if necessary, and arbitrary coordinates as a basis for its survey which is performed simultaneously with that of the higher echelon, adjustment being made after the corrected data have been obtained.

135. Orientation.—*a.* When it is impracticable to initiate survey before dark, and the entire operation must be accomplished during hours of darkness, the initial orientation must be performed with great care. Establishment of direction is the most difficult problem. Where a known direction can be materialized on the ground, usual methods of establishing the direction of instruments are possible. When this cannot be done one of the following methods can be used:

(1) Observation on Polaris.

(2) Arbitrary designation of direction to be corrected when conditions permit.

b. Whatever method of orientation is used in night survey, it should be checked as soon as possible during daylight hours, and the necessary adjustment made to the complete survey.

136. Traverses.—*a.* Traversing at night will normally be by instrument (transit or aiming circle) and by taping or pacing. Stadia is

not a practicable method of measuring distance. With the open sight alidade the plane table is unsatisfactory for night survey, and even with the telescopic alidade it is less convenient to use than is a transit or aiming circle.

b. The methods employed in night traverses, using transit or aiming circle, and taping or pacing for distance, are the same as in day survey. Where traveled roads are used, great care must be taken, as vehicles without lights make it necessary to operate on the side of the road, and to take special precautions to avoid accidents to personnel and damage to equipment.

c. When long shots are made, prearranged signals should be used to identify positively the sighting target and thus avoid gross errors in survey.

137. Intersections and resections.—Employment of intersection and resection in night survey is unusual due to the difficulty of identifying points on the terrain and marking them so that the instrument can sight on them.

138. Plotting and computing.—*a.* While it is possible to carry on computation concurrently with the survey, a more desirable procedure is to perform these operations at the completion of the field work, when a place providing suitable shelter and adequate lighting may be used by the computers and plotters, permitting more accurate work than is possible in the open.

b. Table III gives a reasonable approximation of the accuracy to be expected in survey operations, with instruments and methods that may be used by Field Artillery, and of the time required for survey.

TABLE III

Survey operation	Method	Accuracy 1 in—	Time required per 1,000 yards after start of survey [1]
Traverse	Plane table, open sight alidade, tape, magnetic orientation, plotting to scale of 1:10,000.	150	45 minutes.
	Aiming circle, tape	300	45 minutes.
	Plane table, telescopic alidade, stadia	250	30 minutes.
	Transit and stadia	400	30 minutes.
	1 minute transit and tape, multiple readings to 30″, careful use of tape without corrections.	1,500	1 hour.
	20 second transit and tape	4,000	2 hours.
Intersection [2]	Aiming circle, multiple angles to ½ mil (5-place logs).	500	
	Transit angle to 1 minute (5-place logs)	4,000	
	Transit angle to 30 seconds (7-place logs)	7,000	
Leveling	Trigonometric (transit). Elevation error: Distance.	3,000	1 hour.
	Wye level and Philadelphia rod. Elevation error: Distance.	10,000	2 hours.
	Angle-of-site method (aiming circle)	300	
	Barometric 1 percent to 10 percent error		
Resection	Battle map, 1:20,000:		
	(1) Open sight alidade: 20 yards error.		
	(2) Telescopic alidade: 10 yards error.		
	Map substitutes: Resection unreliable method.		
Night work	About 0.7 as accurate and 3 times as slow as day work.		

[1] 1 hour should be allowed for assembly of party, orientation, and initiation of actual survey.

[2] In intersection the accuracy diminishes rapidly as the angle of intersection diminishes below 30°. The figures quoted are for favorable angles of intersection. For example, an angle of intersection of 10°, using an instrument accurate to 1′, gives an accuracy of 1/500. The results of distant intersections with relatively short bases should be accepted with caution.

Chapter 9

SURVEY PLANS AND EXAMPLES

		Paragraphs
Section I.	Survey plans	139-141
II.	Examples	142-146

Section I

SURVEY PLANS

	Paragraph
Preliminary planning	139
Division artillery plans	140
Battalion plans	141

139. Preliminary planning.—Survey plans for an operation must be started in advance of the operation.

a. The first essential is the issue of suitable maps and air photos or, if maps cannot be furnished, the issue of air photos suitable for use as firing charts. There can be no haphazard substitute for suitable maps or air photos; unless they are available, the survey, no matter how skillfully performed, can be of little value.

b. The second essential is the provision, by higher commanders, of sufficient time for the performance of the survey. When planning an operation, commanders must consider the relative effectiveness of artillery fires with and without survey. At times, speed is paramount and the question of survey is entirely secondary. However, if effective unobserved fires are needed, time must be allowed for the necessary survey. In some situations, the time of initiating an operation should be based primarily on the progress of the artillery survey.

140. Division artillery plans.—When the necessary maps and air photos are available, and the division commander has formulated his plan for the operation, the division artillery commander is ready to make his survey plan and to issue the necessary orders for its execution. The survey plan of the division artillery commander is influenced by the artillery mission, terrain, enemy activity, time available, map or map substitutes furnished, nature of the operation, fires anticipated, and other factors; each situation calls for a different procedure. His plan is concerned mainly with the coordination of the battalion surveys and the allotment of tasks. The artillery commander must decide to what extent the surveys are to be coordinated and the manner in which this is to be accomplished. He decides further what work is to be done by his own survey section in order to provide this coordination and to prevent needless duplication by

subordinate units. Whatever his plan and allotment of tasks, he is habitually faced with the urgent necessity of getting early information to subordinate units so that they may initiate their own surveys in time. There can be no set or routine procedure in the artillery commander's plan; there can be no satisfactory substitute for a knowledge of survey technique.

141. **Battalion plans.**—If provided with suitable maps or map substitutes and information as to the mission, position areas, and sector, a battalion given sufficient time can execute its own survey without assistance. If the division plans to coordinate the various battalion surveys, the battalions should be given early information of the expected coordination and the manner in which it is to be effected. If assistance is to be given in any phase of the survey, the battalion should know what to expect. Other matters, including certain gunnery technique, are of interest to the battalion commander because of their influence on the survey and the construction of the firing chart. Among these are the air photos furnished, the manner of target designation, the possibility of registration, the availability of air observation, information of what survey and registrations he may expect to receive from other battalions, the handling of missions during displacement, and probable fire missions to be executed. Terrain conditions, enemy activity, weather conditions, time available, and the number of hours of daylight remaining also are factors which influence the plan. The conditions are so varied that there can be no standard procedure. Each situation requires an estimate and the adoption of methods suitable under the existing conditions.

SECTION II

EXAMPLES

	Paragraph
General	142
Battalion survey; firing chart—battle map	143
Battlion survey; firing chart—wide-angle photo	144
Battalion survey; firing chart—grid sheet	145
Division survey; firing chart—battle map	146
Division survey; firing chart—wide-angle photo	147
Corps artillery battalion survey; firing chart—grid sheet; wide-angle photo	148

142. **General.**—The examples which follow (pars. 143 to 148, incl.) are drawn to show the survey operations in typical situations. While the methods and principles employed are few and simple, their application is varied to suit the mission, time element, terrain, and other stated conditions.

a. Registration.—Many of the examples deal with situations in which the artillery must be prepared for unobserved fires without registration. This situation has been stressed because a more difficult and more elaborate survey usually is necessary when registrations are not practicable. It should be remembered, however, that registrations should always be made when conditions permit. If registrations are not practicable initially, the survey should be checked by firing at the first opportunity. A check of direction is particularly important; a check of range is also very desirable. The survey plans should prepare for registrations or other checking of the accuracy of the fires by locating suitable observation posts. Registrations in different parts of the target area to give accurate control of the entire sector should be the aim. Looking forward to registration, the survey, if time permits, should tie battalions together so that data obtained by one battalion may be applied to others.

b. Assistance by division artillery section.—The battalion examples, with one exception, illustrate the execution of all necessary survey operations by the battalion survey section with no assistance. When the division artillery survey section is present, battalions normally will be given assistance, as indicated in the examples showing the survey by division artillery.

c. Assistance to incoming artillery.—When reinforcing or other artillery units are due to arrive after dark or at a late hour with little time remaining for survey, the artillery already in the area should, if practicable, perform the survey for these units. The orders of the higher artillery echelon should provide for this assistance. As a minimum, direction should be established for the incoming units.

d. Duties of battalion and battery personnel.—No attempt has been made to show the allocation of duties to batteries, or to show precisely what personnel in the battalion survey section perform any particular operation. In general, the battalion survey section performs the entire battalion survey, calling upon batteries to furnish such personnel to augment the battalion survey section as may be necessary. Often the battery personnel assist in the survey, under battalion direction, and also perform certain battery duties; for example, the marking of the route of the battery into positions, the selection of observation posts, and the necessary steps to facilitate the laying of the battery.

143. Battalion survey; firing chart—battle map.—*a. Example 1* (fig. 46).—(1) *Mission.*—To be prepared for unobserved fires without registration. Speed is required.

(2) *Situation.*—The terrain is gently rolling with scattered woods. *B*, in the target area, can be seen from *A*; both can be identified on the map. *B* has been selected as the base point. The position area cannot be seen from *A*, but it can be seen from *M*, which is visible from *A*; *M* does not appear on the map. The control for the survey is taken from the terrain details that show on the map.

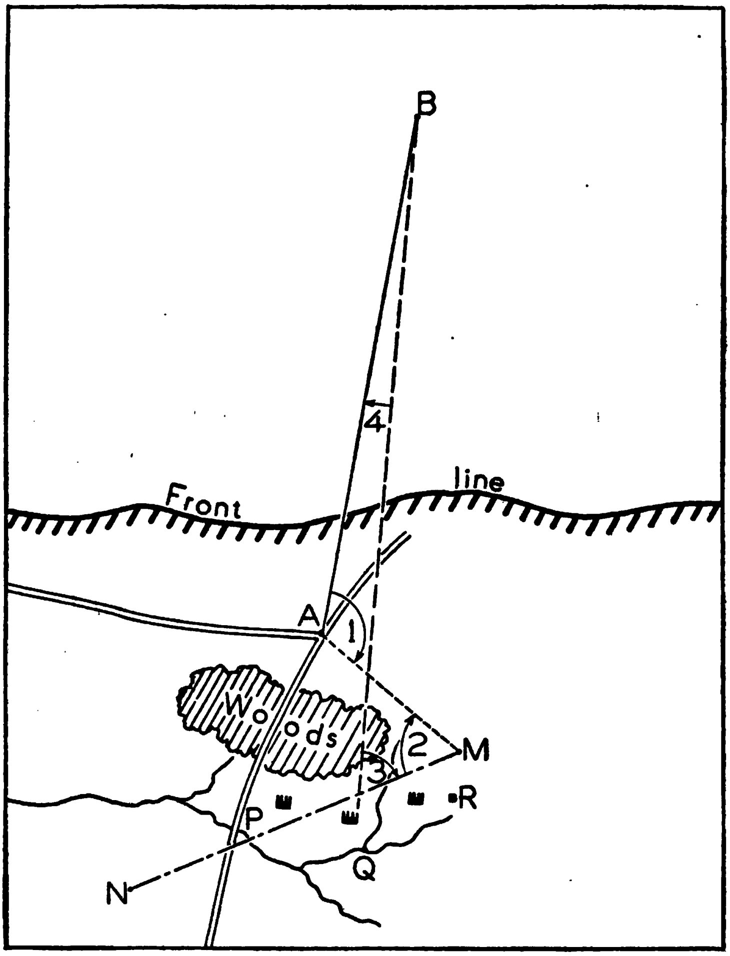


FIGURE 46.

(3) *Survey operations.*—(*a*) *Location of batteries.*—Map locations are determined by traverse from nearby points identified on the map and on the ground; for example, *P*, *Q*, and *R*.

(*b*) *Direction.*—The line *AB* is used to establish direction. Direction is then transmitted to the orienting line *MN* by measuring angles 1 and 2; the batteries take their direction from the orienting line.

(*c*) *Scale.*—Taken from the map.

(*d*) *Vertical control.*—Taken from the contours of the map.

(4) *Remarks.*—It is not necessary to plot the orienting line *MN* on the map. Base angle 3, for example, can be computed, using angles, 1, 2, and 4.

b. Example 2 (fig. 47).—(1) *Mission.*—To be prepared for unobserved fires without registration. Sufficient time is available for precise survey.

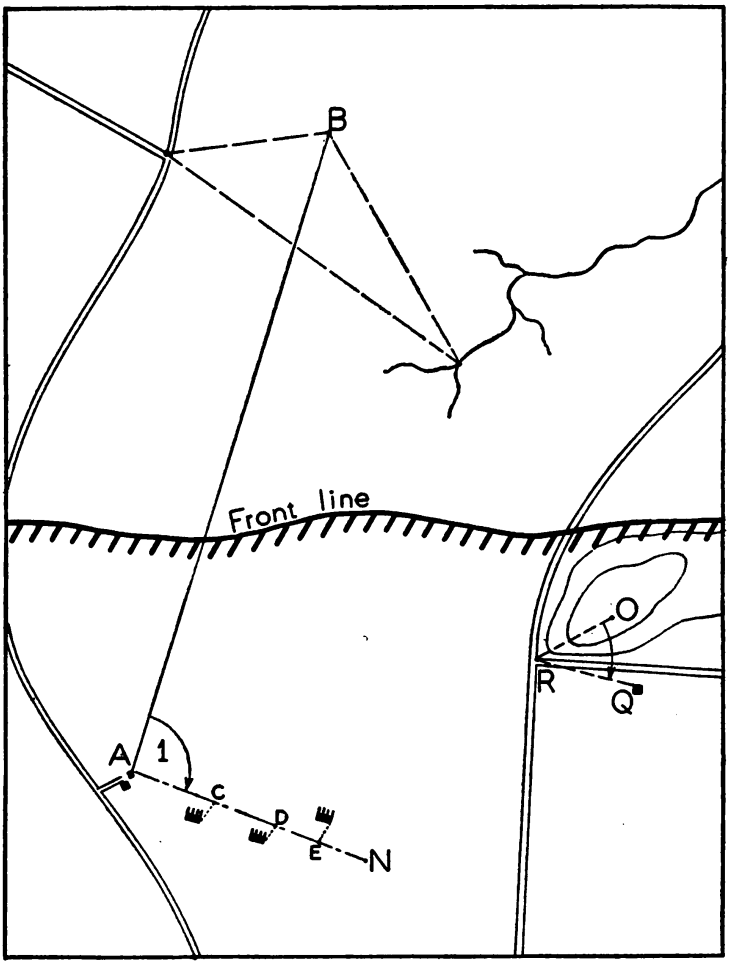


FIGURE 47.

(2) *Situation.*—The terrain is comparatively flat except for low, scattered hills. No point in the target area can be identified on both ground and map. *B*, plainly visible from *A*, can be identified on a recent air photo of the target area, and its position is restituted to the map. The small building at *A* can be identified on the map, and it is visible from most points in the position area. This building and the target area can be seen from a lateral *OP* at *O* (to be

located) but not from the road junction at *R*, which, with the house at *Q*, can be identified on the map. Center-of-impact registrations are expected.

(3) *Survey operations.*—(*a*) *Location of batteries.*—The batteries are located by a traverse from *A*, using angle 1 and taped distances along and from the orienting line *AN*. *C*, *D*, and *E* are place marks. The surveyed positions of the batteries are plotted on the map.

(*b*) *Location of lateral OP's.*—*A* is located on the map by inspection; *O* is located by traverse from *R*.

(*c*) *Direction.*—Direction is established by *AB*. It is transmitted to the batteries, using angle 1 and the orienting line.

(*d*) *Scale.*—Taken from map.

(*e*) *Vertical control.*—Taken from the contours of the map.

(4) *Remarks.*—In this situation, *A* is suitable as one end of the orienting line, thereby simplifying the traverse. The lateral *OP* at *O* need not be located rigidly with respect to *AB*, because one possible reference point, such as *B*, lies in the target area (par. 73*b*). However, if the correct relative locations of *O* and *AB* are doubted, a simple check may be made as follows: An instrument at *A* measures the angle between *B* and *O*; an instrument at *O* measures the angle between *A* and *B*; the length of the line *AB* is accepted as measured on the chart; the triangle *OAB* can now be solved (two angles and a side), and the location of *O* may be checked.

c. *Example 3* (fig. 48).—(1) *Mission.*—After forward displacement, to be prepared without delay for transfers and for observed fires in which the battalion must be brought in based on an adjustment by one battery.

(2) *Situation.*—The terrain is rolling, with little vegetation. *B*, identified on the ground and on the map, can be seen from an *OP* at *O* (not on map). In the position area, certain terrain features on the map can be identified on the ground; for example, the stream junction near *M*, the bridge at *Q*, and the road junction at *R*.

(3) *Survey operations.*—(*a*) *Location of batteries.*—Map locations are determined by inspection or by short traverse (pacing or taping) from terrain features.

(*b*) *Direction.*—An orienting line *MN* is staked out on the ground. The center battery registers on *B*, which is used for a base point. This establishes direction for the battalion. The center battery determines a base angle after firing by referring to an instrument on the orienting line; the base angles of the other batteries are computed, using the angular offsets 4 and 5 measured on the map; for example, angle 2=angle 1+angle 4.

(c) *Scale.*—Taken from the map.

(d) *Vertical control.*—Taken from the contours of the map.

(4) *Remarks.*—During registration by the center battery, the other batteries lay on an arbitrary base angle and shift later when the actual base angle is announced. If the displacement is by battery, the first battery to arrive registers; the other batteries are furnished the base angles on arrival.

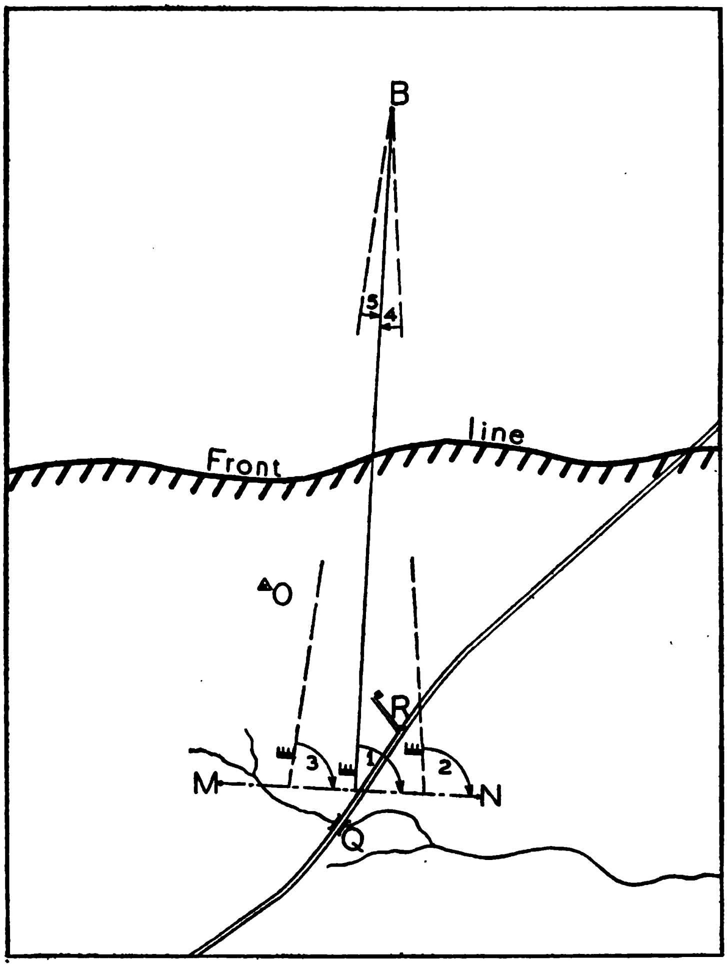


FIGURE 48.

d. *Example 4* (fig. 49).—(1) *Mission.*—To be prepared for unobserved fires without registration. Limited time is available before dark.

(2) *Situation.*—The terrain is slightly rolling and heavily wooded. No points visible in the target area can be identified on the map or on a photo; however, the road junction at *B* has been selected on the map as a base point. There are numerous terrain features in the

position area, such as *Q* and *R*, which are identifiable on the map, but none of them are far enough apart or otherwise suitable for establishing an accurate direction.

(3) *Survey operations.*—(*a*) *Location of batteries.*—Batteries are located accurately with respect to the details of the map by inspection or traverse from points such as *Q* and *R*.

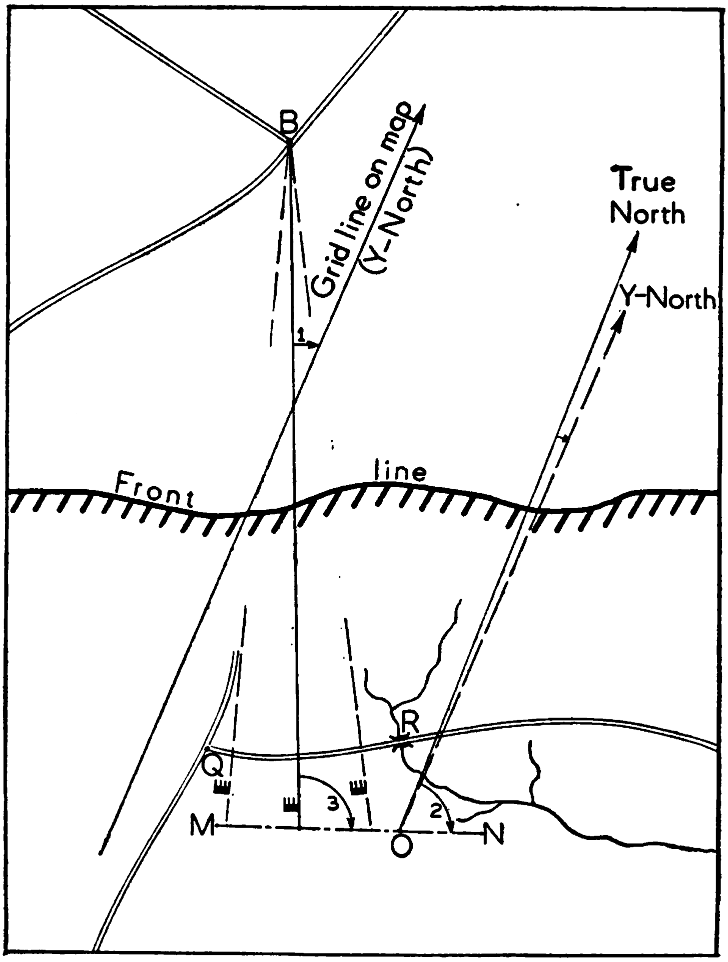


FIGURE 49.

(*b*) *Direction.*—Direction is established by sighting on Polaris. (The angular difference between true north and *Y*-north is shown on the margin of the map.) The *Y*-azimuths of the battery base lines are determined by measuring the angles of intersection with any grid line, for example, angle 1. An orienting line *MN* is staked out on the ground; it need not be plotted on the map. With an instrument set up at *O*, the angle from Polaris to another point on the orienting line is measured. The *Y*-azimuth of the orienting line is

computed by considering the difference between *Y*-north and true north and the deviation of Polaris from true north at the time of sighting. The battery base angles, such as angle 3, may now be computed by comparing the *Y*-azimuths of the base line and the orienting line.

(*c*) *Scale.*—Taken from the map.

(*d*) *Vertical control.*—Taken from the contours of the map.

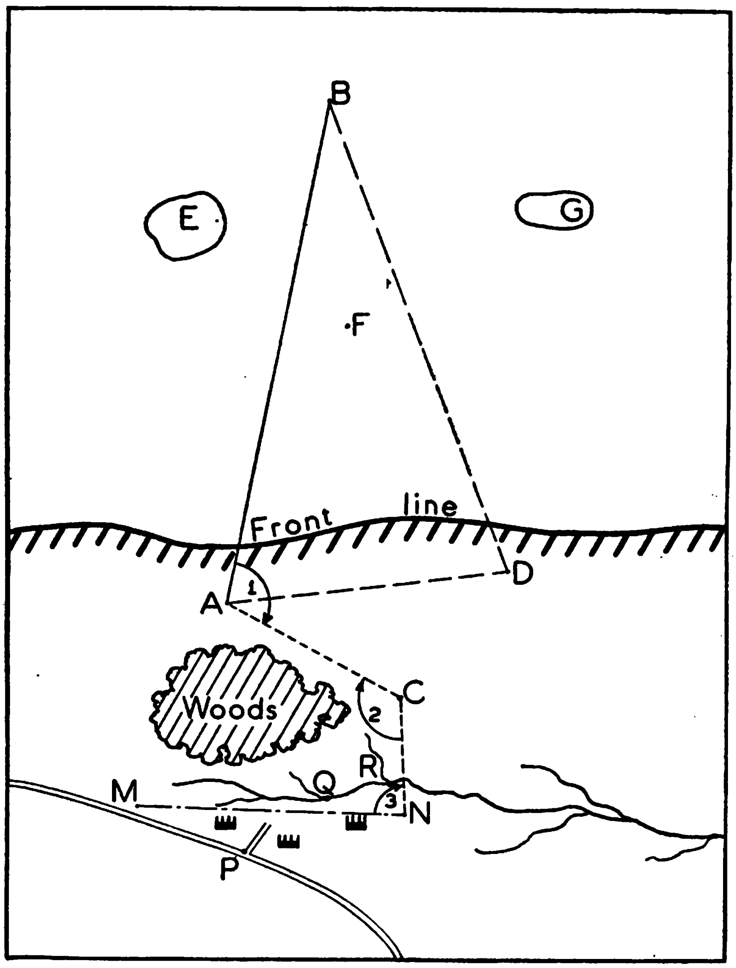


FIGURE 50.

144. Battalion survey; firing chart—wide-angle photo.—*a. Example 5* (fig. 50).—(1) *Mission.*—To be prepared for unobserved fires without registration. Speed is required.

(2) *Situation.*—The terrain is rolling with scattered woods. *B* in the target area can be seen from *A*; both can be accurately identified on the photo. *A*, *B*, and the position area can be seen from *D* (located approximately on the photo).

(3) *Survey operations.*—(*a*) *Location of batteries.*—Photo locations are determined by traverse from nearby points identified on photo and ground; for example, *P*, *Q*, and *R*.

(*b*) *Direction.*—*AB* establishes direction, which is transmitted to the batteries by a directional traverse (angles 1. 2, and 3) and by the orienting line *MN*.

(*c*) *Scale of photo.*—Taken as 1:20,000 until the distance *AB* is determined by computation, using the base *AD*. (When the length of *AD* has been determined, the location of *D* can be accurately plotted with reference to *AB*.)

(*d*) *Vertical control.*—An arbitrary altitude is assigned to *D*. From this point, angles of site are measured to the batteries and to various points or localities in the target area, such as *E*, *F*, and *G* (identified on the photo). Distances are measured on the photo. Altitudes may now be computed.

b. *Example 6* (fig. 51).—(1) *Mission.*—To be prepared for unobserved fires without registration. Sufficient time is available for a precise survey.

(2) *Situation.*—Same as for example 5.

(3) *Survey operations.*—(*a*) *Direction.*—Established by the line *AB*.

(*b*) *Location of batteries.*—By a traverse carrying both distance and direction from *AB*, final legs being run to the batteries from place marks on the orienting line *MN*. Surveyed locations of the batteries are plotted on the photo.

(*c*) *Scale of photo.*—The distance *AB* is determined by computation, using the base *AD*. (When the length of *AD* has been determined, the location of *D* can be accurately plotted with reference to *AB*.)

(*d*) *Vertical control.*—An arbitrary altitude is assigned to *D*. The altitudes of points in the position area and in the target area, such as *E*, *F*, and *G*, are computed, using distances determined from the photo and angles of site measured at *D*.

(4) *Remarks.*—Since more time is available, more altitude control points in the target area should be determined than was done in example 5. Greater precision in direction and scale will result if the photo locations of *A* and *B* are replotted to correct for any relief distortion. (See example 12, par. 144*h*.)

c. *Example 7* (fig. 52).—(1) *Mission.*—To be prepared for unobserved fires without registration. Speed is required.

(2) *Situation.*—No points in the target area can be seen from the position area because of flat, wooded terrain. Within our lines there is sufficient clearing to permit three points, *A*, *B*, and *C*, to

be mutually visible from each other. These points can all be identified on the photo, but the position area cannot be seen from any of them. The bridge at *E* has been selected on the photo as the base point.

(3) *Survey operations.*—(*a*) *Direction.*—Established by *AB*. Transmitted to the batteries by angle 1 and the orienting line *MN*, using a directional traverse from *A*.

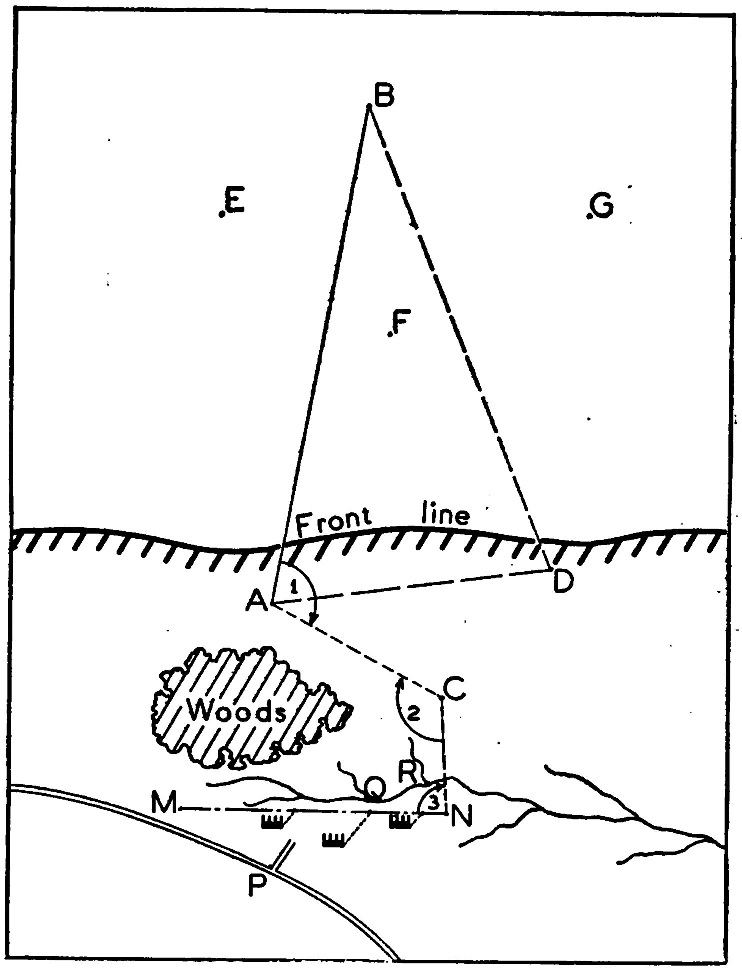


FIGURE 51.

(*b*) *Location of batteries.*—In this situation there is only one terrain feature—the path crossing at *P*—suitable for use in locating the batteries. There is no other point immediately available for establishing the initial direction needed for the short traverses to the battalion. This direction can be furnished by having the orienting line pass through *P*. Through the photo location of *P* a line is plotted making the angle 1 (already determined from the direc-

tional traverse) with *AB*. The battery traverses are plotted along and from this line. (The photo location of *N* does not matter; this point is staked on the ground only for the directional traverse.)

(*c*) *Scale.*—First determined from the taped distance *AC* along the road; later from the computed distance *AB*, using angles 2 and 3. (Preferably, scale should be determined from the distance between two points at least 2,000 yards apart.)

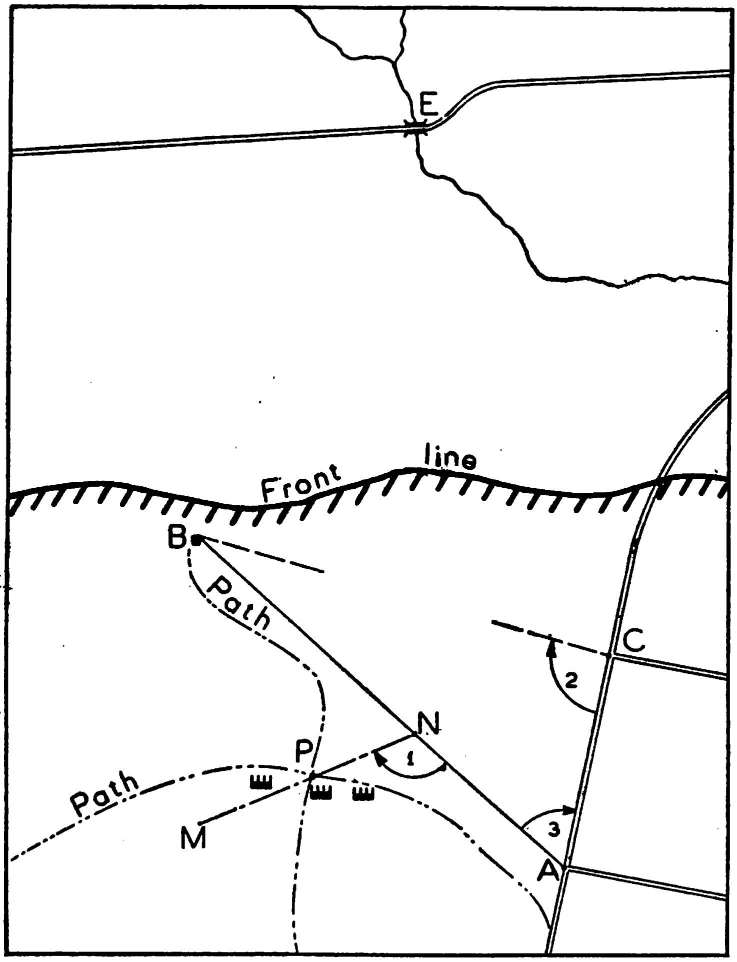


FIGURE 52.

(*d*) *Vertical control.*—Immaterial because of flat terrain.

(4) *Remarks.*—In this situation, no point in the target area has been included in the ground survey. After the opening of fire, efforts must be made to check the accuracy of the fires as computed, using, if available, air or forward ground observers.

d. Example 8 (fig. 53).—(1) *Mission.*—To be prepared for unobserved fires without registration. Limited time is available before dark.

(2) *Situation.*—Because of flat, wooded terrain no points in the target area are visible from the position area or areas nearby. However, *B* can be seen from *A*, which is a considerable distance to the right; both points can be identified on the photo. The division artil-

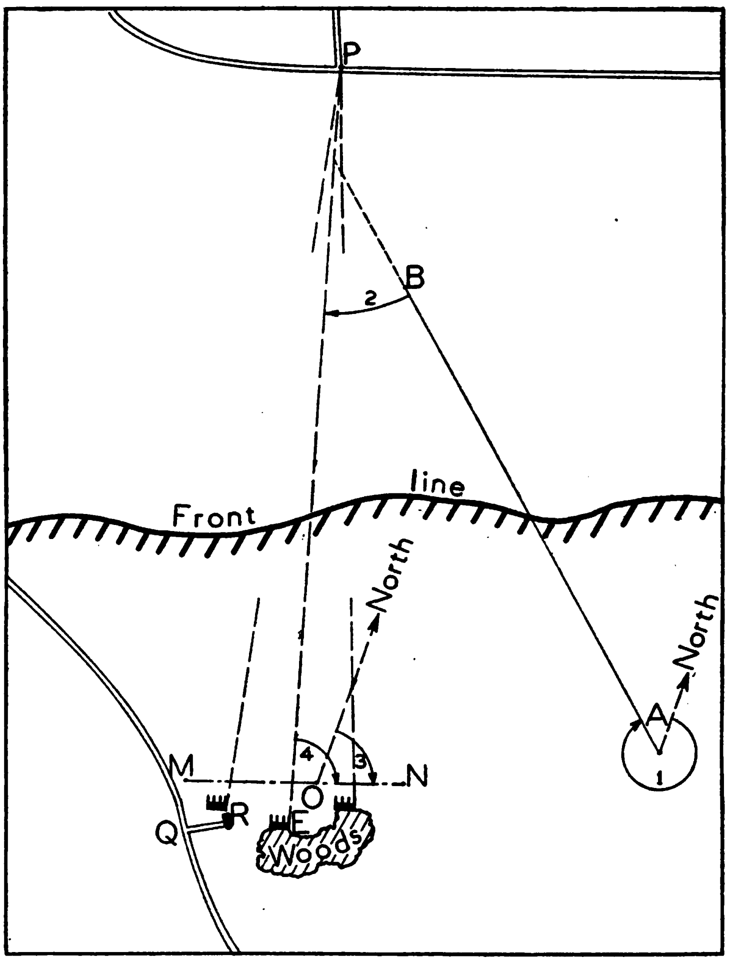


FIGURE 53.

lery survey section is to determine the azimuth of *AB* at a specified time by sighting on Polaris. At the same time a battalion instrument set up at *O* will also sight on Polaris. The position of this star at this time will be considered as north, and all azimuths in the division will be referred to this direction. The orienting line *MN* is staked out on the ground conveniently near all batteries; it need not be plotted on the photo. The road junction at *P* has been selected on the photo as the base point.

(3) *Survey operations.*—(*a*) *Location of batteries.*—By inspection or short traverse from nearby terrain features appearing on the photo, such as *Q*, *R*, and the woods.

(*b*) *Direction.*—Established by the line *AB*, whose azimuth is determined by angle 1. The azimuth of the base line *EP* of the center battery is determined by measuring angle 2 on the photo. The azimuth of the orienting line *MN* is determined by angle 3, measured

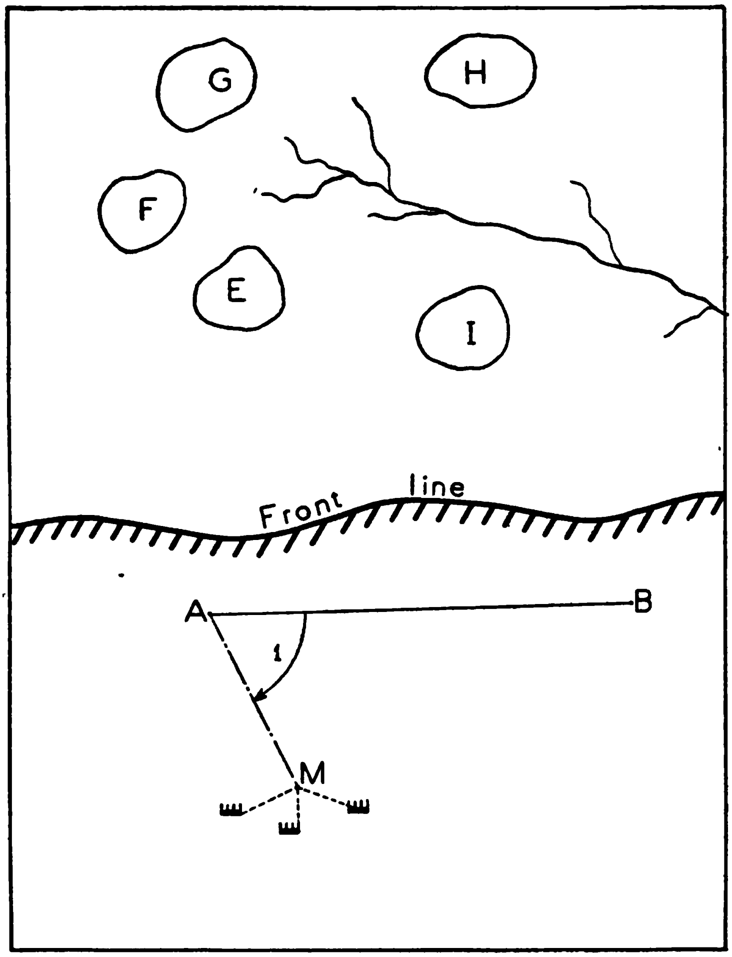


FIGURE 54.

from Polaris. Knowing the azimuths of these three lines, the angle between any two of them, such as the base angle (angle 4), may be computed by comparing azimuths.

(*c*) *Scale.*—Furnished by the division artillery survey section.

(*d*) *Vertical control.*—Immaterial because of flat terrain.

e. Example 9 (fig. 54).—(1) *Mission.*—To be prepared for unobserved fires with transfers. Time is available for precise survey.

(2) *Situation.*—The terrain is open, eroded, slightly rolling, with scattered vegetation. There are several small terrain features in the target area that can be seen, but none of them, or any other points in this area, can be identified on both ground and photo. The target area can be seen from *A* and *B* within our own lines; both of these points can be identified on ground and on photo. From *M*, on a low crest, all three batteries and the point *A* can be seen.

(3) *Survey operations.*—(*a*) *Direction.*—Established by *AB* and transmitted to the batteries by angle 1 and the orienting line *AM*. *M* is within calling distance of all three batteries.

(*b*) *Location of batteries.*—By traverse for both distance and direction from *A*, surveyed locations being plotted on the photo.

(*c*) *Scale.*—Established by taping the length of *AB*.

(*d*) *Vertical control.*—An arbitrary altitude is assigned to *A*. Altitudes of the batteries are computed, angles of site being included in the traverse. From *A*, angles of site are measured to general localities *E*, *F*, *G*, *H*, and *I*. These localities can be identified on the photo, although well-defined points cannot. Altitudes for these areas are computed, using approximate ranges measured on the photo. In this situation, the measurements and computations for vertical control in the target area have no connection with accurate horizontal control.

(4) *Remarks.*—The direction given the batteries by survey is corrected later by registration. Three centers of impact in different parts of the target area, one by each battery, are pin-pointed on a photo by an air observer who drops this photo at the battalion command post. In the absence of air observation, a center-of-impact registration could be conducted from lateral OP's at *A* and *B*.

NOTE.—A center of impact is the center of a group of bursts fired rapidly from a single piece using the same deflection and elevation setting.

f. Example 10 (fig. 55).—(1) *Mission.*—After forward displacement, to be prepared without delay for transfers and for observed fires in which the battalion must be brought in based on an adjustment by one battery.

(2) *Situation.*—The terrain is gently rolling and wooded. *B*, in the target area, may be identified on the ground and on the photo.

(3) *Survey operations.*—(*a*) *Location of batteries.*—By inspection or short traverse from nearby terrain features, such as the building at *P* and the group of trees at *Q*.

(*b*) *Direction.*—Established by registering the center battery on *B*, which is used as the base point. After registration, base angle 1 is determined by referring to an instrument on the orienting line *MN*; this line is staked out on the ground but is not plotted on the photo.

The base angles of the other batteries are computed by using the angular offsets 2 and 3, measured on the photo.

(*c*) *Scale.*—Accepted initially at 1:20,000; determined later by survey if time is available.

(*d*) *Vertical control.*—By estimation with relation to *B*; improved later by survey if practicable.

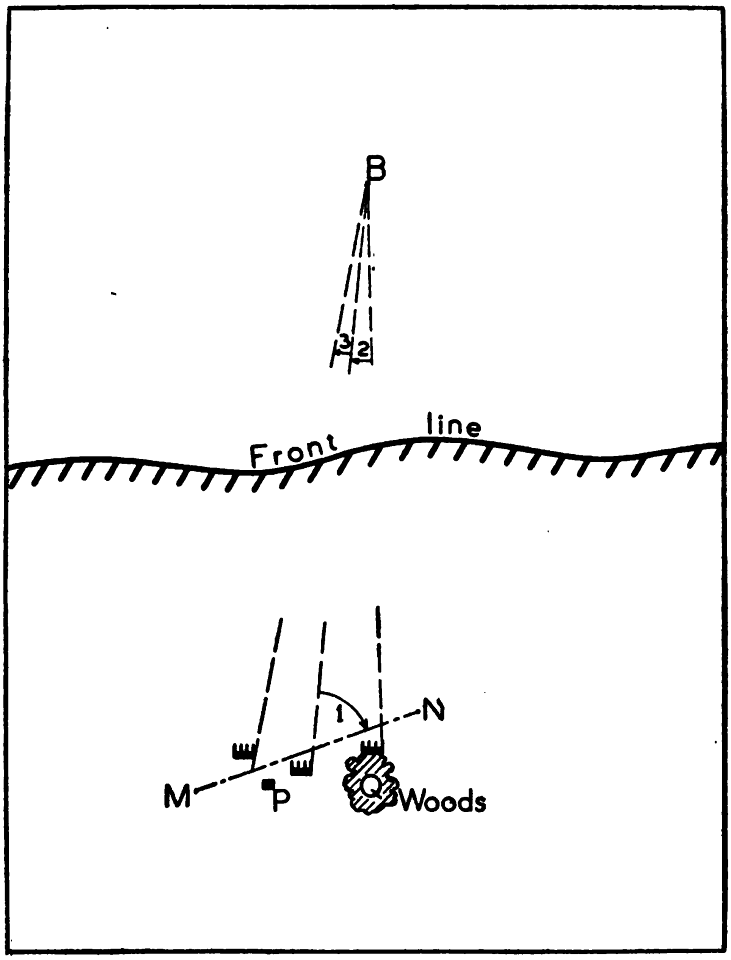


FIGURE 55.

(4) *Remarks.*—In favorable terrain, an air burst approximately above the base point may be used to give direction to the other batteries. In such case, no orienting line is needed.

g. Example 11 (fig. 56).—(1) *Mission.*—After forward displacement, to be prepared without delay for unobserved fires, using transfers; and, in case of an adjustment by one battery, to be prepared to bring in the other two batteries.

(2) *Situation.*—The terrain is gently rolling and wooded. No points in the target area can be identified on both photo and ground.

In the position area, such terrain features as *P*, *Q*, *R*, and *S* can be identified on the photo. Points *B*, *C*, and *D* are reported by an air observer as the photo locations of three centers of impact fired in rapid succession by the center battery, which displaced before the other two.

(3) *Survey operations.*—(*a*) *Location of batteries.*—By inspection or short traverse with respect to terrain features in the position area.

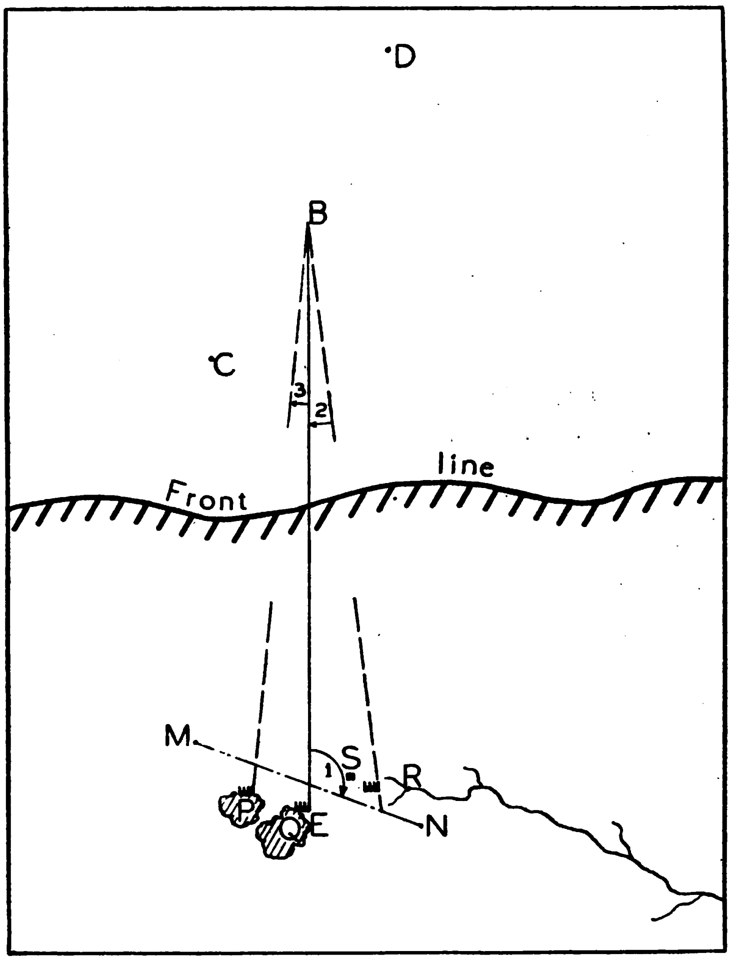


FIGURE 56.

(*b*) *Direction.*—Established by center-of-impact registrations; for convenience, base deflections are recorded on the registration at *B*. After registration, base angle 1 is determined by referring to the orienting line *MN*, which is staked out on the ground but is not plotted on the photo. The other base angles are determined by applying angular offsets 2 and 3 on the photo to the base angle for the center battery.

(c) *Scale.*—Accepted as 1:20,000 until a check by survey can be made.

(d) *Vertical control.*—Since the terrain is not rugged and no points in the target area can be seen from the immediate vicinity of the position area, vertical control is obtained by estimating, from the photo, relative altitudes, with respect to *B*, *C*, and *D*, the centers of impact; allowance also is made for estimated or computed differences in altitude of the registering and nonregistering batteries.

(4) *Remarks.*—(a) Later, when more time is available, accessible points may be found from which the target area can be seen. A more accurate survey will then be possible, including vertical control.

(b) With an air observer, groups of rounds can be fired in rapid succession and their centers of impact determined. When more than one group is practicable, they furnish some measure of vertical control, compensate for errors in scale, and give a better command of the target area.

h. Example 12 (fig. 57).—(1) *Mission.*—To be prepared for unobserved fires without registration. Speed is required.

(2) *Situation.*—(a) The terrain in the position area is rugged, with plateaus and canyons; the terrain in the target area is smoother, with low, eroded hills. The effects of relief distortion must be corrected to give satisfactory results. The wide-angle photo was taken from an altitude of about 20,000 feet above the average ground level. *A*, *B*, and *N* are identified on both ground and photo. *B* and *N* are visible from *A*. No point in the target area identifiable on the photo can be seen from *N*. The position area can be seen from *N* but not from *A*.

(b) Approximate altitudes: *A*, 1,800 feet; position area, 1,300 feet; *B*, 1,600 feet (this is also the approximate average altitude of the target area).

(3) *Survey operations.*—(a) *Location of points within our lines.*—*A* and *N* are located by inspection; the batteries are located by inspection or short traverse with respect to nearby terrain features. All points are then replotted to a datum plane of 1,600 feet.

(b) *Direction.*—Established by the replotted position of *AB*, and transmitted to the orienting line *MN* by angles 1 and 2.

(c) *Scale.*—Determined initially by taping the distance *AN*, in conjunction with the directional traverse *A–N–M*. Later, the length of *AB* is computed when *P*, on high ground to the left front, can be occupied (*P* need not be identified on the photo). This computed length is compared to the replotted length on the photo. The photo location of *N* is used only to determine the initial scale.

(*d*) *Vertical control.*—The altitude of *A* is known to be approximately 1,800 feet and is arbitrarily accepted as such. The altitudes of points in the position area are determined by angle-of-site readings taken in conjunction with the traverse. Angles of site are read from *A* to localities in the target area which are generally identifiable on the photo.

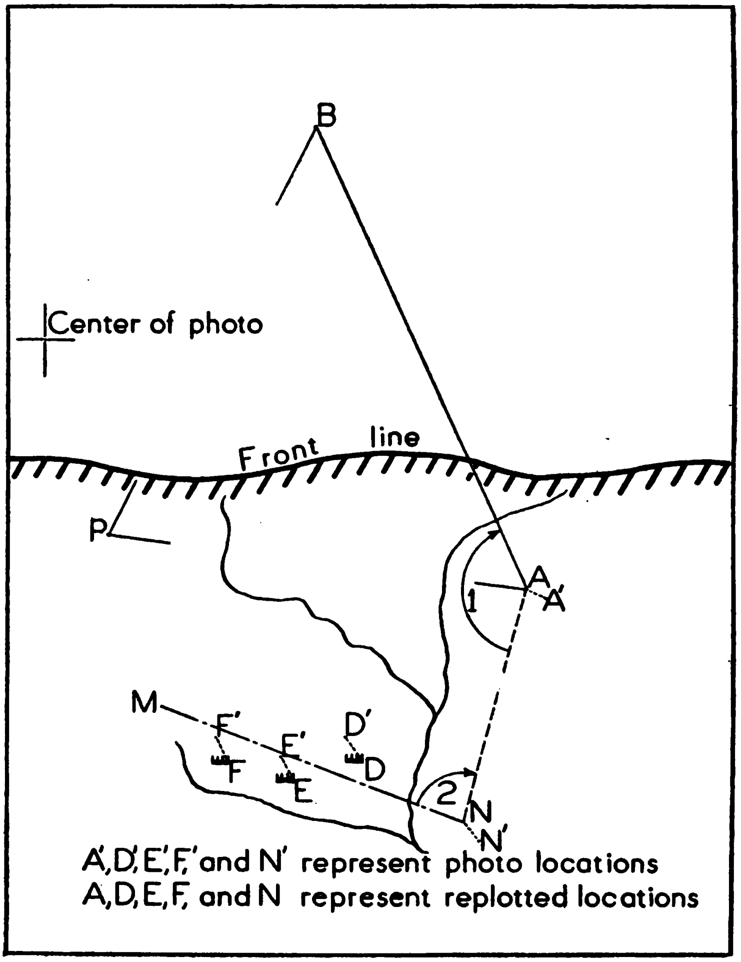


FIGURE 57.

(4) *Remarks.*—As a general rule, the datum plane for the firing chart should be chosen so as to reduce replotting to a minimum. Therefore, in this problem, this plane was chosen to fit the smoother terrain of the target area, while the batteries and other essential points within our own lines were replotted. Relative distortion of targets, with respect to this plane, should be small or negligible.

NOTE.—A check on the accuracy of replotting *A* and *N* can be made by comparing the photo angle *BAN* with its ground measurement.

145. Battalion survey; firing chart—grid sheet.—*a. Example 13* (fig. 58).—(1) *Mission.*—To be prepared for unobserved fires without registration; fires are not immediately required but time is limited.

(2) *Situation.*—The terrain is rolling with low hills; the countryside is well dotted with farm houses and other buildings. An air

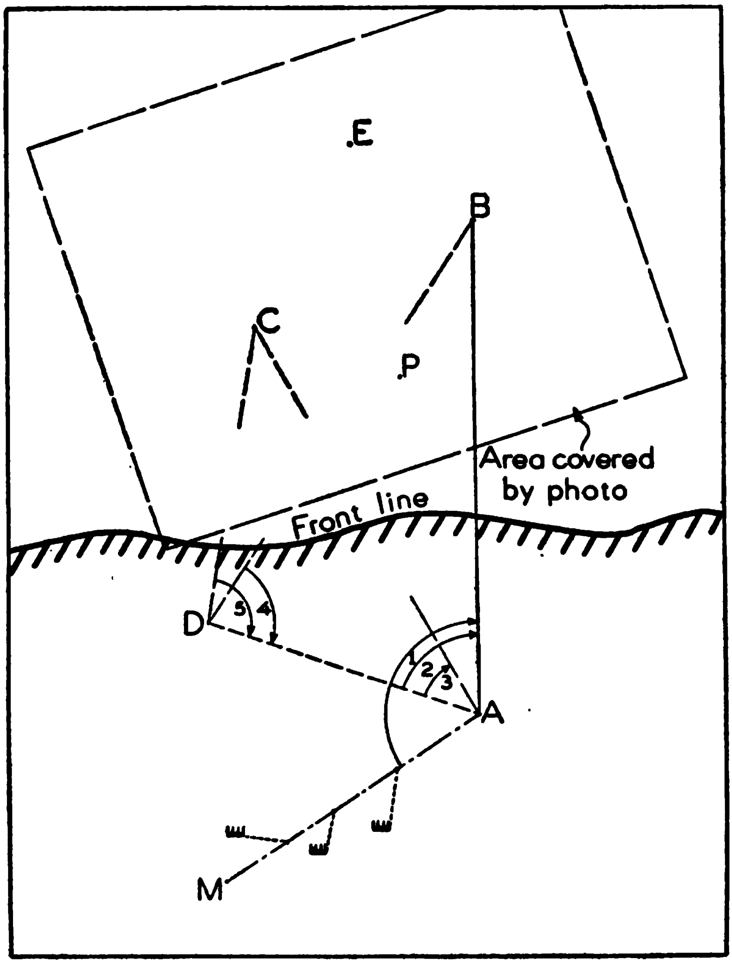


FIGURE 58.

photo covering most of the target area is available. On it are two points, *B* and *C*, which can be identified from both *A* and *D*. *A* and *D* are visible from each other. The position area can be seen from *A*. No ground control has been furnished by the division artillery survey section, and none is expected in time to carry out the mission.

(3) *Survey operations.*—(*a*) *Direction.*—Arbitrarily established by *AB* whose direction is determined approximately with a declinated instrument. Direction is transmitted to the batteries by angle 1, then along and from the orienting line *AM*.

(*b*) *Location of batteries.*—By traverse, from *A*, carrying both distance and direction. An arbitrary grid is established.

(*c*) *Scale.*—Established by plotting to a 1:20,000 scale on a grid sheet.

(*d*) *Control of air photo of target area.*—The length of the short base *AD* is taped; its direction is determined by angle 2. Using this base and angles 2, 3, 4, and 5, the grid sheet locations of *B* and *C* are determined. These points then control restitution from the photo.

(*e*) *Vertical control.*—*A* is assigned an arbitrary altitude. Angles of site are included in the position-area traverse. From *A*, the site is measured to all points in the target area, such as *E* and *P*, that can be identified on the photo.

(4) *Remarks.*—In this situation, the survey operations require considerable time. Every effort should be made to get the survey section in the area as quickly as possible. Early information of the position area is essential. All survey possible should be done before the batteries arrive.

b. *Example 14* (fig. 59).—(1) *Mission.*—To be prepared for unobserved fires, using transfers. Little time is available.

(2) *Situation.*—The terrain is covered with low hills and woods. A strip of three small vertical air photos is available and is hastily assembled; it covers both position and target areas, but it is not of fire-control scale. Point *B*, visible from *O* but not from *M* and *N*, can be identified on a photo. Points *M* and *N* on the photo are easily identified in the position area. No common control has been furnished by the division artillery survey section, and none is expected in time to carry out the mission.

(3) *Survey operations.*—(*a*) *Location of batteries.*—By inspection or short traverse with respect to identified terrain features such as *P*, *Q*, and *R*. An arbitrary grid is established.

(*b*) *Direction.*—Determined basically by registering the center battery on *B*, using an *OP* at *O*, and comparing the referred base angle with the measured angle on the photo. This will serve as a check on the direction error caused by hastily assembling the strip of photos. The other batteries are laid for direction, using the angular offsets 2 and 3.

(*c*) *Scale.*—Determined initially by taping the distance *MN* and comparing ground distance with photo distance.

(*d*) *Vertical control.*—Determined initially by estimating relative altitudes with respect to *B*, the point of registration, allowances also

being made for any computed or estimated differences in the altitudes of the registering and nonregistering batteries.

(4) *Remarks.*—(*a*) Since the photos are not of fire-control scale, all necessary points are transferred to a grid sheet as soon as the direction corrections from registration and the scale of the photos become known. It should be possible to determine a scale of fair

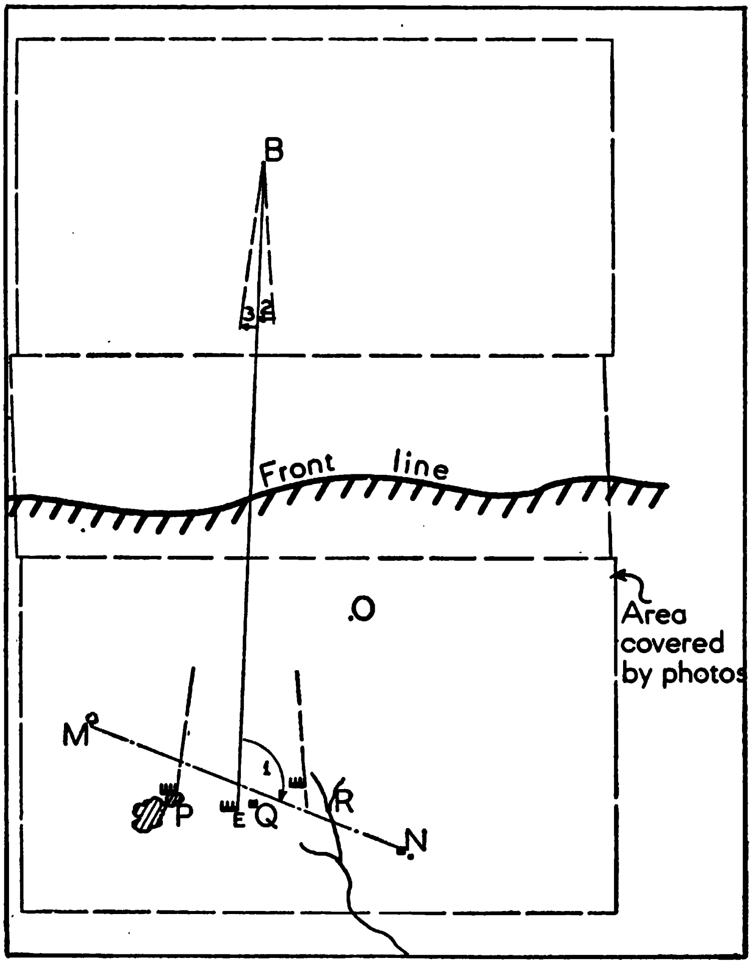


FIGURE 59.

accuracy before registration is completed, because the small single vertical photo usually has good clarity of detail and a minimum of distortion, as compared to the wider photos. Therefore the taping of relatively shorter distances will give satisfactory results. The relative locations of the point *B* and the batteries should be sufficiently accurate until a more detailed survey can be made for improving scale and ground control.

(*b*) This situation illustrates a hasty survey of fair accuracy made

possible by registration. Small errors of scale would normally be included in the range corrections determined from registration. If the scale of the strip were not determined before the completion of registration, the distance *EB* may be plotted according to the adjusted range; under some circumstances this may be just as accurate.

(*c*) The mosaic may also be used as the firing chart. Distances can be converted quickly by a slide rule with a fixed setting (par. 89); angular measurements are unaffected by scale.

(*d*) If registration were not permitted and more time were available, it would be necessary to determine accurately the ground distance *EB* and from it establish the scale of the mosaic. This scale might not be the best for the strip as a whole, but it would be accurate for distances from the position area to the target area.

c. Example 15 (fig. 60).—(1) *Mission.*—To be prepared for unobserved fires without registration. Time is available for a precise survey.

(2) *Situation.*—The terrain is rolling with scattered woods. A photo of the target area is available. Common-control coordinates and the altitudes of *A*, *B*, *C*, and *D* will be furnished later by the division artillery survey section. *B* and *C* are visible from *D*; they can be identified on the photo. *B* is the only point that can be seen from *A*.

(3) *Survey operations.*—(*a*) *Direction.*—Established by *AB*, which is part of the expected common control.

(*b*) *Location of batteries.*—By traverse from *A*, carrying both distance and direction.

(*c*) *Scale.*—A 1:20,000 grid sheet is used; the given points are plotted, using coordinates.

(*d*) *Vertical control.*—Obtained from the common control furnished by the division artillery survey section. The altitudes of the batteries are determined from the traverse. From *D*, angles of site are measured to various points, such as *E*, *F*, and *G*, which can be identified on the photo. The altitudes are determined later when the restituted positions of these points are plotted on the grid sheet.

(*e*) *Control of photo.*—The line joining *B* and *C* is used as a base for restitution. If the coordinates of these points are furnished in time, it will not be necessary to determine their locations by short-base methods as was done in example 13.

(4) *Remarks.*—In a situation of this type, the battalion habitually will base its survey on those points which have previously been designated on the ground as part of the common control system. Later, when the coordinates of these points become known, the battalion sur-

vey network can be superimposed quickly and accurately on the common control points. If the coordinates and altitudes of these points are not furnished in time for initial use, the battalion still has its own local horizontal control, while for vertical control an arbitrary altitude may be assumed.

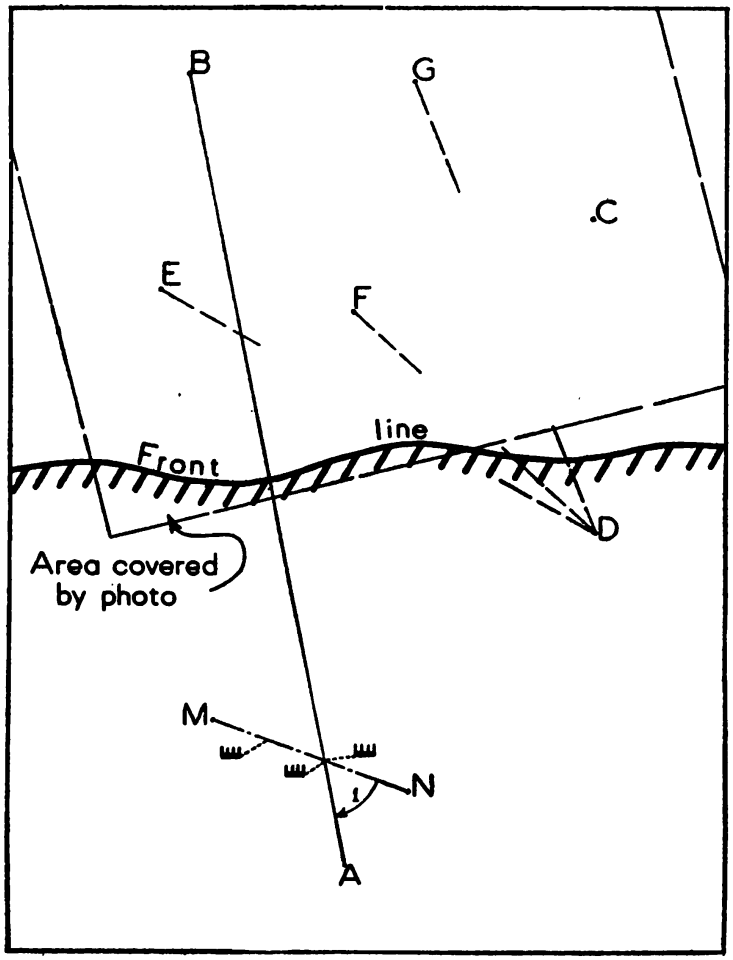


FIGURE 60.

d. Example 16 (fig. 61).—(1) *Mission.*—To be prepared for unobserved fires without registration. Time is available for a precise survey.

(2) *Situation.*—Photos of the target area are available. Common-control coordinates and the altitudes of *A*, *B*, and *C* will be furnished later by the division artillery survey section. Both *B* and *C* can be seen from *A*. *B* can be identified on the photo; *C* cannot. A reinforcing battalion of medium artillery must be included in the survey. A 1:62,500 geological map with 20-foot contour intervals is available.

(3) *Survey operations.*—(*a*) *Direction.*—Established by *AB* and transmitted to the batteries through angles 1, 2, and 3; then from the orienting lines *MN* and *MO*.

(*b*) *Location of batteries.*—By traverse from *A*, carrying both distance and direction.

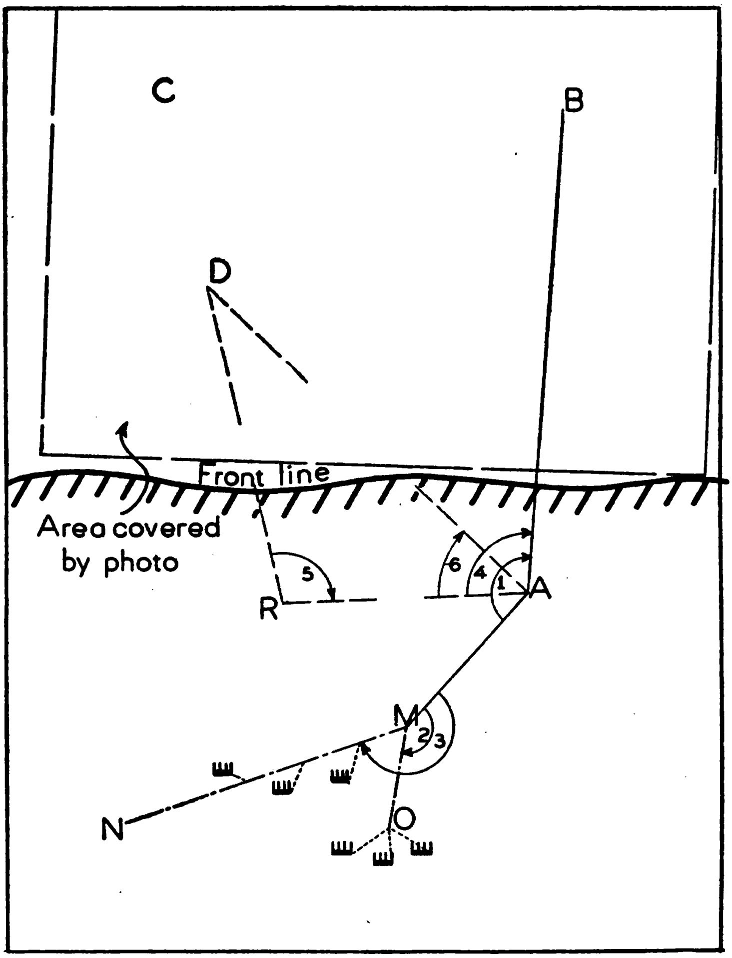


FIGURE 61.

(*c*) *Scale.*—A 1:20,000 grid sheet is used; the given points are plotted, using their coordinates.

(*d*) *Vertical control.*—Taken from the 1:62,500 geological map with 20-foot contour intervals.

(*e*) *Control of photo of target area.*—Since *C* cannot be identified on the photo, it is necessary to determine the grid-sheet location of *D*, which is identified on the photo and is visible from *A* and *R*, the ends of a short base. *B* and *D* are then used for restitution of points and targets.

e. Example 17 (fig. 62).—(1) *Mission.*—To be prepared for unobserved fires without registration. Time is available for a precise survey.

(2) *Situation.*—The terrain is rolling with scattered woods and numerous farm buildings. A wide-angle photo is available; it covers

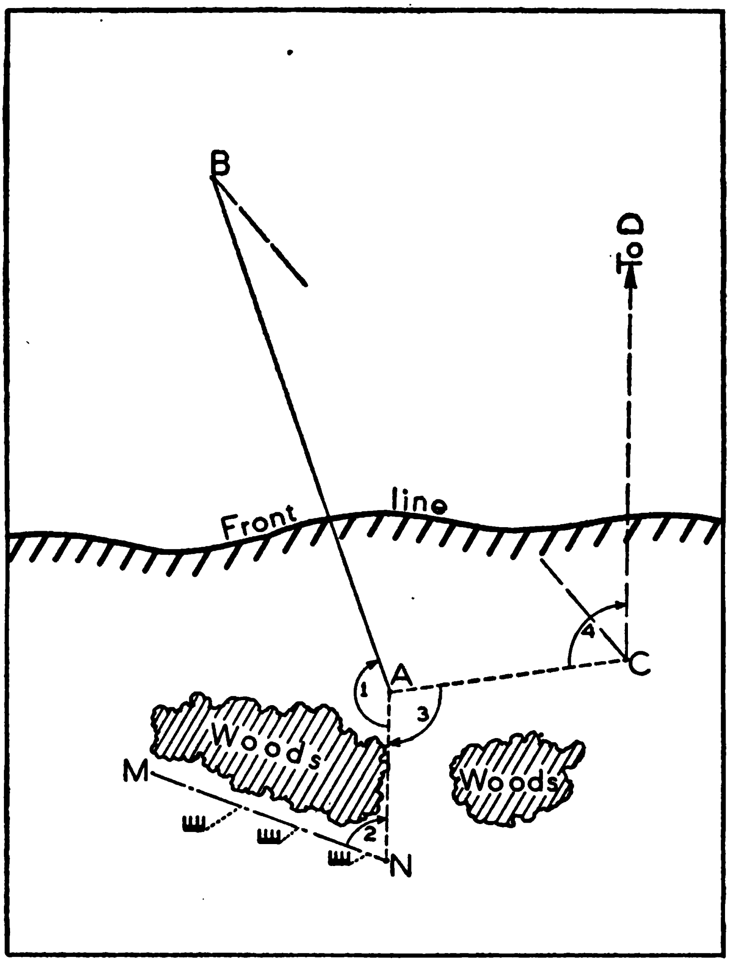


FIGURE 62.

both position and target areas. The division artillery survey section will furnish later (as a part of common control) the coordinates and altitude of the point *C* and the *Y*-azimuth from this point to *D*, which can be seen in the distance but cannot be identified on the photo. Points *A* and *B* can be identified on the photo; *C* cannot. *B*, *C*, and *N* are visible from *A*. *N* cannot be seen from *C*. The position area cannot be seen from either *A* or *C*. The wide-angle photo will be used as a firing chart for targets conveniently designated thereon; but for targets designated by common-control coordinates, a grid sheet will be used.

(3) *Survey operations.*—(*a*) *Direction.*—For the photo, the line *AB* establishes direction; for the grid sheet, the *Y*-azimuth of the line *CD*.

(*b*) *Location of batteries.*—For the photo, by traverse from *A*, taking initial direction from *AB;* for the grid sheet, by traverse from *C*, taking initial direction from *CD*. Each traverse carries distance, direction, and angles of site. The surveyed locations of the batteries are plotted on the photo and on the grid sheet when the common control becomes available.

(*c*) *Scale.*—For the photo, the length of *AB* is computed, using the base *AC*. The grid sheet is gridded for a 1:20,000 scale.

(*d*) *Vertical control.*—Based upon the altitude of *C*, which is furnished. Altitudes of the batteries are determined from the traverse. For the target area, angles of site are measured from *C* to various points and general localities that can be identified on the photo. These points and localities can be transferred to the grid sheet with an accuracy sufficient for vertical control on this sheet.

(4) *Remarks.*—In this situation, surveys for both the photo and grid sheet were carried on simultaneously. When the coordinates of *C* and the *Y*-azimuth of *CD* are announced, the broken-line traverse *C–A–N–M* can be quickly plotted on the grid sheet. Two firing charts are used; data for some targets can be more easily determined from the photo and others from the grid sheet.

146. Division survey; firing chart—battle map.—*Example 18* (fig. 63).—*a. Mission.*—To be prepared to deliver massed unobserved fires without registration. Sufficient time is available for a precise survey.

b. Situation.—The terrain is rolling, with scattered woods and farm buildings. *A* and *B*, identifiable within our lines, are control points used by the army engineers for constructing the battle map; their coordinates are known; an instrument set up at either point can be seen from the other. A few buildings in the target area, such as *C* and *D*, can be seen from *A* and identified on the map.

c. Survey operations.—(1) *Direction.*—Established by the line *AB*, whose *Y*-azimuth is computed from coordinates.

(2) *Location of batteries.*—By battalion traverses carrying both distance and direction. The division locates convenient points, such as *E* and *F*, on the line *AB* for use by the battalions in starting their traverses.

(3) *Scale.*—The scale of the battle map is 1:20,000.

(4) *Vertical control.*—Taken from the contours of the map.

d. Remarks.—In this example, direction was not established by a line running from the target area to the position area because there were no visible points in this area whose accuracy of location could compare with those of *A* and *B*. However, as a check against errors of survey and against the accuracy of the map, ground angles such as *CAB* and *DAB* should be compared to the corresponding map angles.

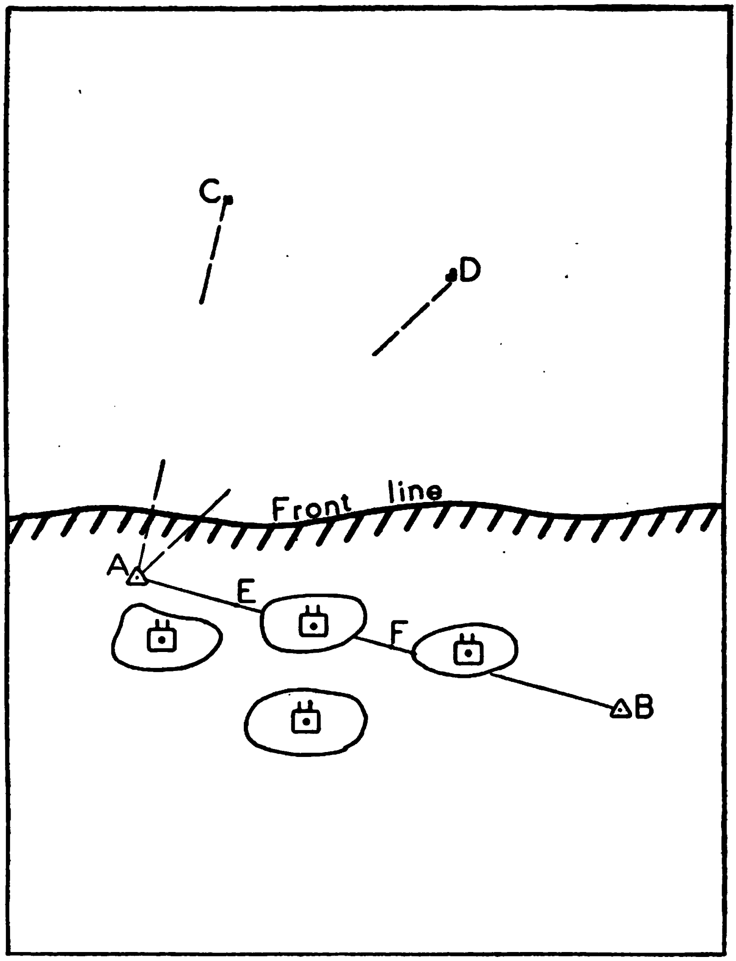


FIGURE 63.

147. Division survey; firing chart—wide-angle photo.—*a. Example 19* (fig. 64).—(1) *Mission.*—To be prepared to deliver massed unobserved fires without registration. Speed is required.

(2) *Situation.*—The terrain is rolling with scattered vegetation. *B* is visible from *A* and *F*. *A* and *B* are identifiable in the photo; *F* is not. The division artillery survey section arrived in the area with the first reconnaissance echelons.

(3) *Survey operations.*—(*a*) *Location of batteries.*—Each battalion locates its batteries by inspection or by short traverse with respect to nearby terrain features.

(*b*) *Direction.*—Established for the division by the line *AB*; transmitted to all battalions by a directional traverse from *A* to their position areas.

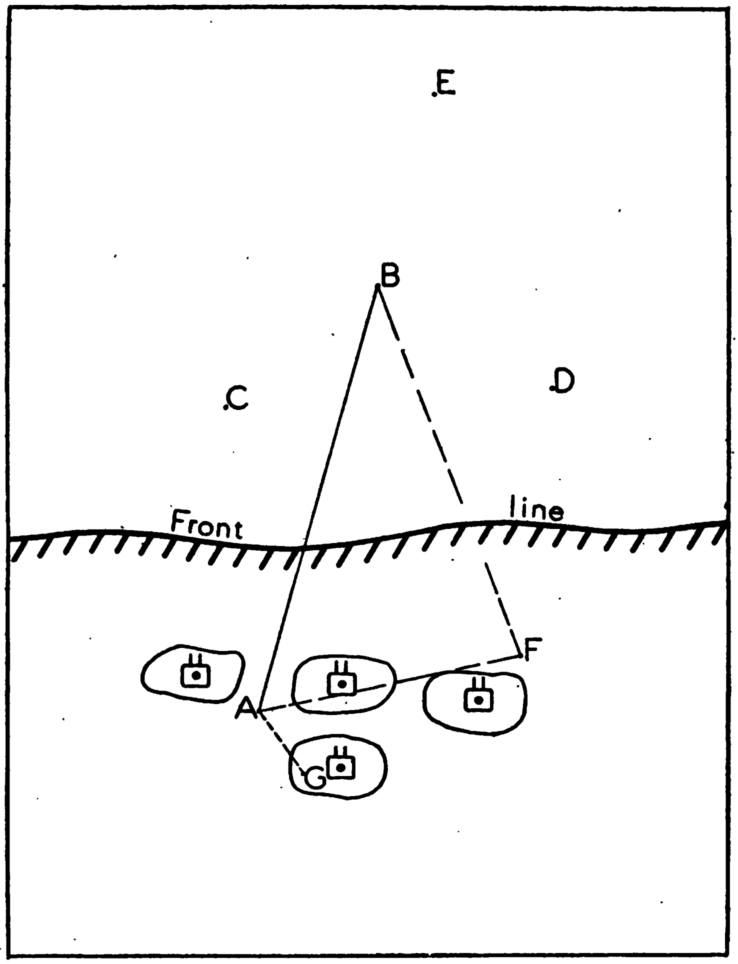


FIGURE 64.

(*c*) *Scale.*—Determined by computing the length *AB*, using the base *AF*.

(*d*) *Vertical control.*—The altitude of *A* is arbitrarily established. Altitudes of other points for vertical control are then determined—*G* and *F* in the position area; *B*, *C*, *D*, and *E* in the target area.

(4) *Remarks.*—(*a*) In case the division artillery survey section is unable to perform all the operations enumerated above, specific battalions are assigned to assist.

(*b*) When the survey is completed, the fires of the division artillery may be massed, without previous registration, on any target located on the photo. Since all battalions have the same basic direction, any correction determined by one battalion may be applied to the others. Therefore when registration becomes practicable, or if there is surveillance by an air observer, corrections for both direction and range may be made.

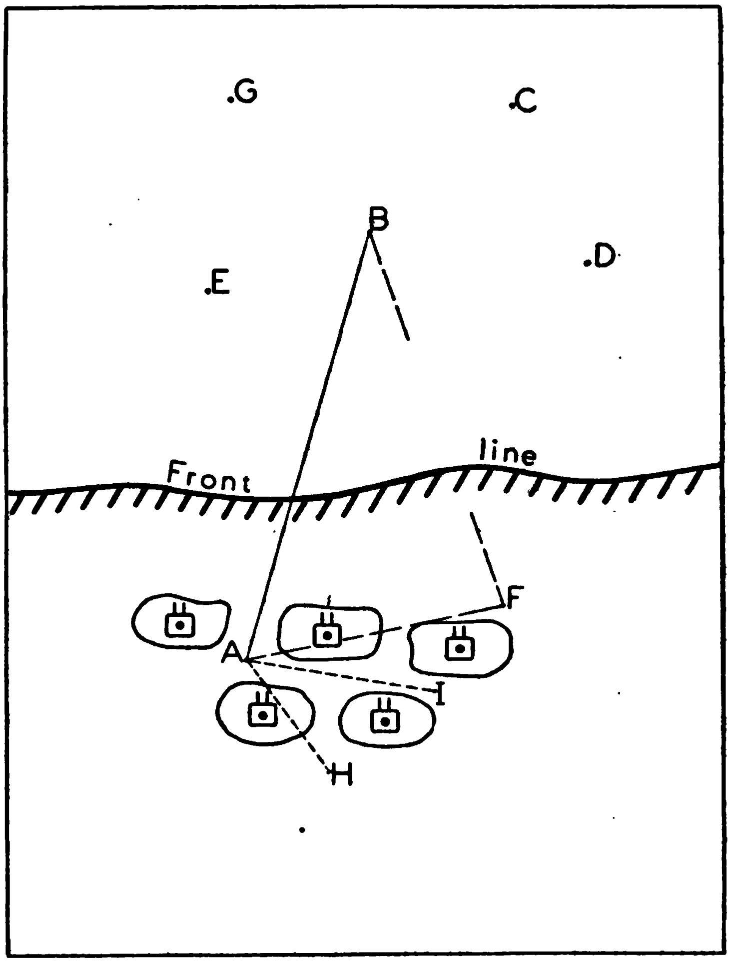


FIGURE 65.

(*c*) In some situations, time and effort may be saved if the division section, with an instrument at *A*, measures the directions to points conveniently near the position areas. This will assist each battalion with the initial portion of its directional traverse.

b. *Example 20* (fig. 65).—(1) *Mission*.—To be prepared to deliver unobserved fires without registration. Sufficient time is available for a precise survey.

(2) *Situation.*—The terrain is rolling with scattered vegetation. *B* is visible from *A* and *F*. *A* and *B* are identifiable on the photo; *F* is not. The division artillery survey section arrived in the area with the first reconnaissance echelons. The altitude of *A* is furnished by the corps observation battalion.

(3) *Survey operations.*—(*a*) *Direction.*—Established by the line *AB*; transmitted to the battalions by traverse from *A*.

(*b*) *Location of batteries.*—Surveyed locations are plotted by each battalion, the traverse from *A* carrying distances as well as direction.

(*c*) *Scale.*—Determined by computing the length *AB*, using the base *AF*.

(*d*) *Vertical control.*—Altitudes of points for vertical control are determined by angle-of-site readings from *A*—*F*, *H*, and *I* in the position area; *B*, *C*, *D*, *E*, and *G* in the target area.

(4) *Remarks.*—As compared to example 19, greater accuracy may be expected because the batteries are located accurately in relation to *AB*. It will be noted that the control and coordination are comparable to those of the fire-control grid. This method of providing coordination is actually preferable to that of the fire-control grid because of the difficulty, if not impracticability, of placing an accurate grid on the photo.

c. Example 21 (fig. 66).—(1) *Mission.*—To be prepared to deliver massed unobserved fires without registration.

(2) *Situation.*—The terrain in the position area and in most of the target area is flat or slightly rolling and heavily wooded, making any traverse difficult. Little daylight remains. *B* can be seen from *A*; both are indentifiable on the photo. *A* is in the only locality which affords a general view of both position and target areas. There are no points in the target area that can be identified on both ground and photo.

(3) *Survey operations.*—(*a*) *Direction.*—Established by simultaneous readings on Polaris. The division establishes the azimuth of *AB* at the prescribed hour; at the same time each battalion determines the azimuth of its orienting line.

(*b*) *Location of batteries.*—Determined by inspection or by short traverse with respect to nearby terrain features.

(*c*) *Scale.*—Determined by taping the distance *AB*.

(*d*) *Vertical control.*—Because of the flat terrain, any corrections for vertical control will be small or negligible. However, as a check, angles of site are read from *A* to various localities in the position and target areas that can be generally identified on the photo.

(4) *Remarks.*—This method generally provides an accurate direc-

tion for the battalions and is quicker than a traverse. The sun or moon, when near the horizon, may be used in a similar manner. In such cases, accurately synchronized watches are necessary. If there is an appreciable difference in the altitudes of *A* and *B*, the points should be replotted to a common datum plane; the photo direction of the line *AB* will then be accurate.

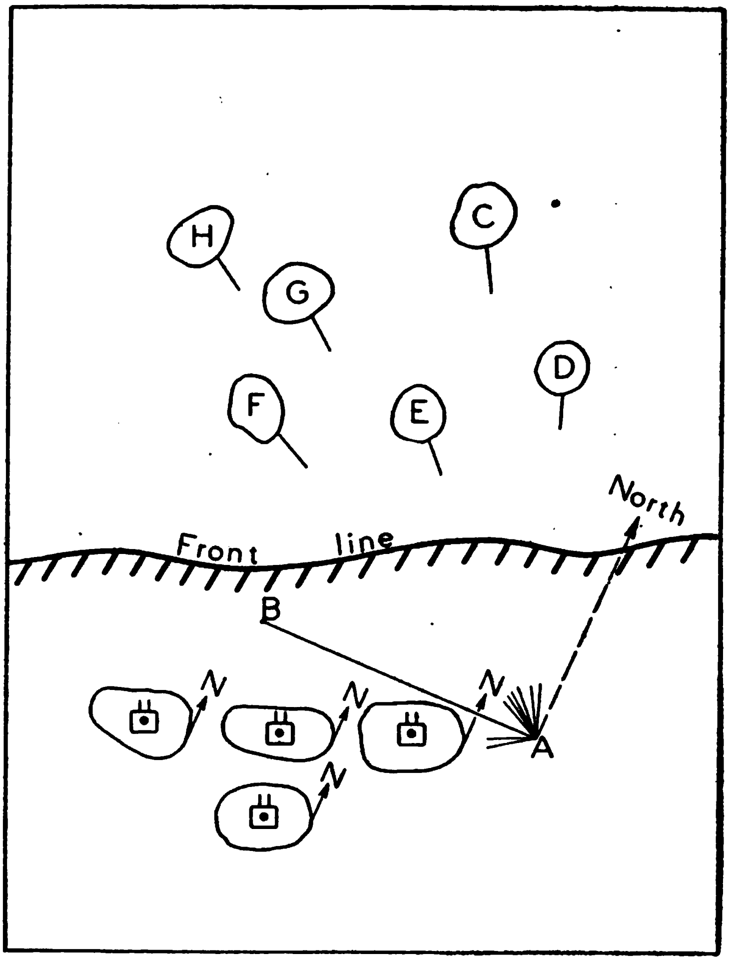


FIGURE 66.

d. Example 22 (fig. 67).—(1) *Mission.*—To be prepared to deliver massed unobserved fires without registration. Sufficient time is available for a precise survey.

(2) *Situation.*—The terrain in both the position and target areas is broken with plateaus and hills of different elevations. The effects of relief distortion must be corrected to give satisfactory results. *B* can be seen from *A*; both can be identified accurately on the photo; the altitude of *A* is known from available topographic data.

(3) *Survey operations.* — (*a*) *Datum plane.* — Established by the division at 1,800 feet, which is the average ground level of the target area.

(*b*) *Direction.*—Established by the division for all battalions, using the replotted location of the line *AB*.

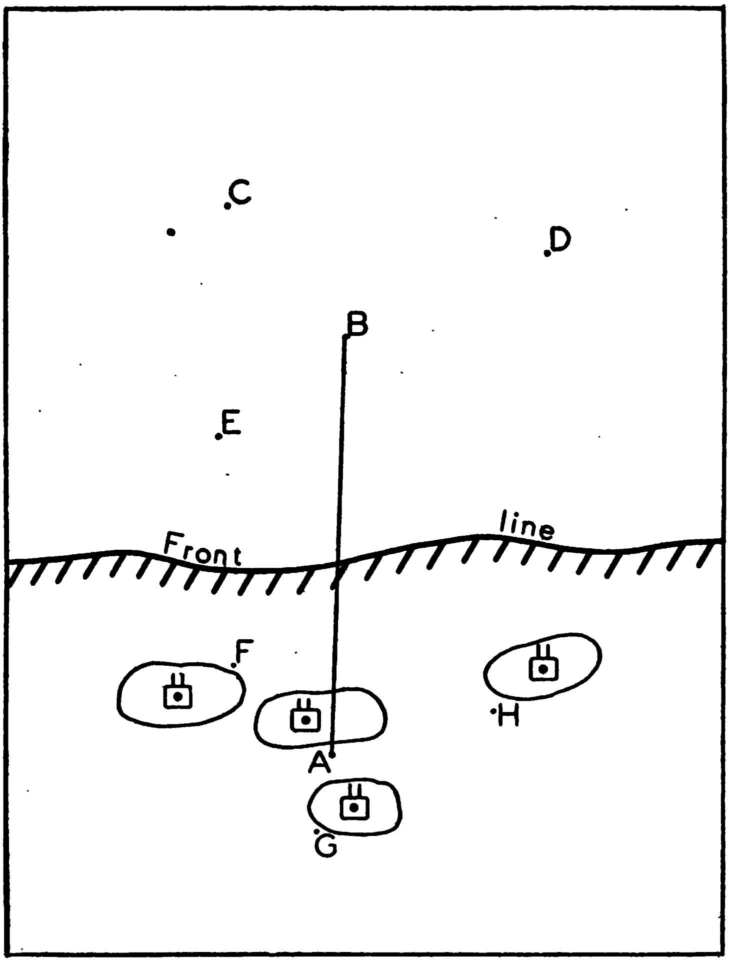


FIGURE 67.

(*c*) *Location of batteries.*—By battalion traverses from *A*, carrying both distance and direction. Since the replotted position of *AB* is used, this traverse automatically places all batteries on the prescribed datum plane.

(*d*) *Scale.*—Determined by the division. The computed length of *AB* (computed by short-base methods) is compared to its replotted length. It is announced to the battalions, for example, as 1:20,800 at 1,800 (altitude of datum plane of all firing charts).

(*e*) *Vertical control.*—From the known altitude of *A*, common-

control altitude is carried forward by the division to altitude control points *B*, *C*, *D*, and *E* in the target area, and to *F*, *G*, and *H* in the position area.

(4) *Remarks.*—The same accuracy can be obtained if each battalion selects its own datum plane and plots all critical points to that plane, including points upon which registrations have been made. A correction obtained by one battalion can still be applied to the others. However, for simplicity, a common datum plane is preferable.

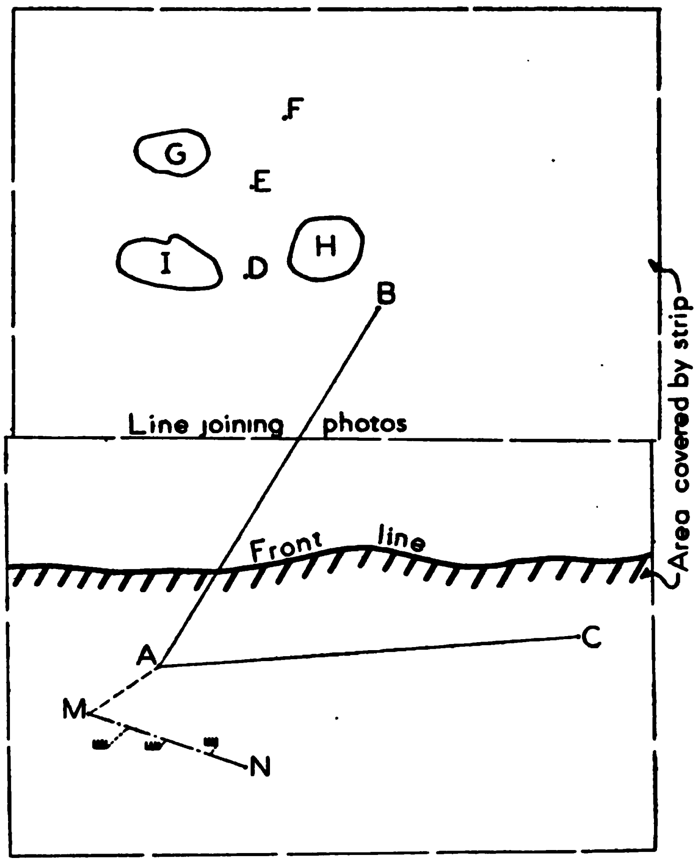


FIGURE 68.

148. Corps artillery battalion survey; firing chart—grid sheet; wide-angle photo.—*Example 23* (fig. 68).—*a. Mission.*—To be prepared for unobserved fires, initially without registration. Time is available for a precise survey.

b. Situation.—(1) The battalion consists of three batteries of 155-mm guns. A strip consisting of two wide-angle photos is available as a firing chart for any targets or points designated with respect to the arbitrary grid of either photo. A grid sheet will be used as a supplementary firing chart for targets reported with re-

spect to the common-control grid used by the corps observation battalion and radio-intercept units.

(2) *A* and *C* have been selected as observation posts for the azimuth instruments used in flash ranging. The coordinates and altitudes of these points are expected shortly. The position area can be seen from *M* but not from *A* or *C*. From *A* can be seen the high ground in the general localities *G*, *H*, and *I*. These localities can be recognized on the photo, but well-defined points therein cannot be identified. Several points in the target area, such as *D*, *E*, and *F*, show plainly on the photo, but because of defilade they cannot be seen from within our lines. *B*, near the edge of the target area, is the only point visible from *A* and *C* which can be positively identified on both ground and photo. Its coordinates and altitude will be furnished by the observation battalion as soon as computations can be made from the readings of the azimuth instruments at *A* and *C*.

c. Survey operations.—(1) *Direction.*—For the strip of photos, taken from the line *AB*; for the grid sheet, from *AC*.

(2) *Location of batteries.*—By traverse from *A*, carrying both distance and direction. *AB* orients the traverse for the photos; *AC* for the grid sheet. Surveyed locations are plotted on the photo and on the grid sheet.

(3) *Scale.*—For the photos, by computing the length of *AB* using coordinates, and comparing this distance with the distance *AB* on the strip. Since this line extends across both photos somewhat in the direction of range, it should furnish, in some measure, corrections for both deflection and range.

(4) *Vertical control.*—For both photo and grid sheet, by traverse to the position area, and by angles of site from *A* to various localities in the target area. For defiladed targets, some estimation will be necessary; if two photos are available, stereoscopic examination may help.

d. Remarks.—The point *B* is at a considerable distance from the center of the target area. If air observation is possible, an early check should be made by firing. The photo locations of centers of impact fired in rapid succession at such points as *D*, *E*, and *F* would furnish the necessary corrections. Even if the observer could remain in the air only long enough to locate one such center of impact, the information would be valuable.

INDEX

	Paragraphs	Pages
Adjusting traverse	65	45
Advantages:		
Long-base intersection	72	50
Survey with a grid sheet	117	89
Aiming circle:		
Centering the needle	41	30
Declinating	42	30
Laying instrument on a given Y-azimuth	43	30
Measuring:		
Horizontal angles	39	29
Vertical angles	40	29
Traverses	64	45
Use	38	29
Air photographs	10, 85–87, 106–114	4, 64, 83
Angles:		
By repetition	50	36
Measuring and plotting with protractor	26	16
Assembly, strip mosaic	91	71
Center-to-center method	92	71
Reconnaissance method	93	72
Back-azimuth resection	69	47
Base angle:		
Determination	124	92
Error	125	93
Base pieces, location	123	91
Basic survey operations	57	40
Basis of survey	5	3
Battalion plans	141	103
Battalion survey operations	17, 143–145	9, 104
Batteries:		
Horizontal location	100, 106	79, 83
Transmission of direction to	102, 108	80, 85
Battery survey operations	18	9
Battle maps	100–105	79
Bessel (Italian) method of resection	70	48
Center-to-center method, assembly of strip mosaic	91	71
Centering needle, aiming circle	41	30
Characteristics, night survey	128	96
Classification, horizontal angles	48	35
Common control	8, 9, 112, 118	4, 87, 89
Computation, locating a point by	77	53
Computing in night survey	138	100

INDEX

	Paragraphs	Pages
Construction, firing chart to reduce relief distortion	111	86
Controlled mosaics	120	90
Coordinates	22, 29	12, 20
Calculation	81	58
Plotting a point from	23	12
Corps survey operations	14, 148	7, 135
Declination, instruments	42, 105, 114	30,82,88
Definitions	19, 60, 67, 71	10, 41, 46, 50
Description, fire-control grid	21	11
Determination:		
Base angle	124	92
Direction:		
By use of—		
Battle map	101	79
Wide-angle photo	107	84
Distance to points in battalion area	79	56
Length of base	78	54
True north by rapid methods	83	60
Direction:		
Air photographs	88	67
Transmission of, to batteries	102, 108	80, 85
Disadvantages:		
Long-base intersection	72	50
Survey with a grid sheet	117	89
Distances and Y-azimuths from coordinates, calculation	80	57
Distances, measuring and plotting	27	18
Division artillery plans	140	102
Division survey operations	15, 147	8, 129
Engineer cooperation in artillery survey	4	2
Equipment, night survey personnel	133	98
Error of base angles	125	93
Examples, survey operations	142–148	103
Fire-control grid	21–27	11
Firing charts	98, 99, 111	78, 86
GHQ and army survey operations	13	6
Grids	20–28	10
Grid sheet	115–118	88
Horizontal angles:		
Classification	48	35
Measuring with—		
Aiming circle	39	29
Transit	49	35
Horizontal location, batteries and targets	100, 106	79, 83
Inspection, location of a point by	59	40
Instruments:		
Declination	42, 105, 114	30,82,88
Lights	130	97

	Paragraphs	Pages
Instruments—Continued.		
Used for survey operations	30	22
Intersection:		
Long-base	71–73	50
Method of restitution	95	74
Night survey	137	100
Short-base	74–79	52
Latitude	3	2
Laying aiming circle on a given Y-azimuth	43	30
Length of base, determination	78	54
Lights, instruments	130	97
Locating a point by—		
Computation	77	53
Inspection	59	40
Location of base pieces	123	91
Long-base intersection	71–73	50
Measurements, tape	34	24
Measuring:		
Angles with a protractor	26	16
Coordinates of a point	24	15
Distances	27	18
Horizontal angles	39, 49	29, 35
Vertical angles	40, 51	29, 36
Y-azimuth	44	31
Methods:		
Intersection:		
Long-base	73	50
Short-base	74	52
Restitution:		
Radial-line	97	76
Ratio	96	75
Survey	55	39
Transit traverse	61, 63	41, 42
Modern air photos	10	4
Mosaics	90–93, 119–122	71, 90
Night occupation of position, preparation	126	94
Night survey:		
Characteristics	128	96
Intersections and resections	137	100
Orientation	135	99
Plotting and computing	138	100
Requirements	127	96
Training personnel for	129	97
Traverses	136	99
Oblique triangles, solution	76	53
Observation posts	104, 113	82, 87
Operations, necessary in construction of firing chart	99	78
Orientation	58, 135	40, 99

INDEX

	Paragraphs	Pages
Personnel:		
Training in night survey	129	97
Traverse party	61	41
Plane table:		
Accessories	31	22
Traverses	64	45
Use	32	23
Planning in survey	139	102
Plotting:		
Angles with protractor	26	16
Distances	27	18
In night survey	138	100
Point from coordinates	23	12
Traverse	66	46
Polar coordinates	29	20
Practicability and desirability, common control	9	4
Precision and accuracy in survey	56	39
Preparation, night occupation of position	126	94
Purpose, field artillery survey	4	2
Radial-line method of restitution	97	76
Range poles	53	37
Ratio method of restitution	96	75
Reconnaissance method, assembly of strip mosaic	92	71
Regiment survey operations	16	8
Relation of photos to ground	87	65
Requirements, night survey	127	96
Resection:		
Definition	67	46
In night survey	137	100
Methods:		
Back-azimuth	69	47
Bessel (Italian)	70	48
Tracing-paper	68	46
Responsibility, common control	8	4
Restitution	94–97	74
Right-angled scale, use	25	15
Right triangles, solution	75	53
Scale, air photographs	89, 110	68, 86
Setting up transit	47	34
Short-base intersection	74–79	52
Sighting targets, night survey	131	97
Simultaneous observations	84	63
Solution of triangles:		
Oblique	76	53
Right	75	53
Stadia	54	37
Station markers, night survey	132	98
Straight line, to run or prolong with a transit	52	36
Strip mosaic, assembly	91–93, 122	71, 91

INDEX

	Paragraphs	Pages
Survey:		
Air photos, use in	10, 85–87, 106–114	4, 64, 83
Basic operations	55–84	39
Basis	5	3
Common control	8, 9	4
Echelons	12–18	6
Engineer cooperation	4	2
Equipment and its use	30–54	22
Examples	142–148	103
Governed by situation	6	3
Night	127–138	96
Plans	139–141	102
Procedure	98–126	78
Purpose	4	2
Time required	7	3
Training	11	5
Tables of Organization	2	2
Tape	33	23
Tapemen:		
Duties	36, 62	27, 41
Training	37	28
Taping methods	35	26
Targets:		
Horizontal location	100, 106	79, 83
Sighting, night survey	131	97
Target-designation grid	28	20
Time required in survey	7	3
Tracing-paper resection	68	46
Training in survey	11	5
Transit	45–54	31
Transmission of direction to batteries	102, 108	80, 85
Traverse:		
Adjusting	65	45
Aiming circle and plane table	64	45
Definitions	60	41
Duties, tapeman	62	41
Methods and personnel	61	41
Methods of transit	63	42
Night	136	99
Plotting	66	46
True north, determination by rapid methods	83	60
Types of—		
Air photos	86	64
Mosaics	90	71
Uncontrolled mosaics	121	90
Verniers	46	31
Vertical angles, measuring	40, 51	29, 36
Vertical control	103, 109	82, 85

INDEX

	Paragraphs	Pages
Wide-angle photo	106–114	83
Y-azimuth, measuring	44	31

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